VOL. 32, NO. 7 JULY, 1955

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Published Monthly by the AMERICAN JOURNAL OF OPTOMETRY PUBLISHING ASSOCIATION,
1502 Foshay Tower, 821 Marquette Ave., Minneapolis 2, Minn.

ANNUAL SUBSCRIPTION, UNITED STATES and CANADA $6.00. FOREIGN $6.50.
Single copies, 60c

Entered as second-class matter, February 20, 1924, at the post office at Minneapolis 2, Minnesota, under the Act of March 3, 1879
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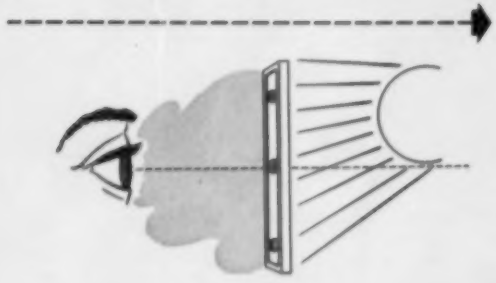

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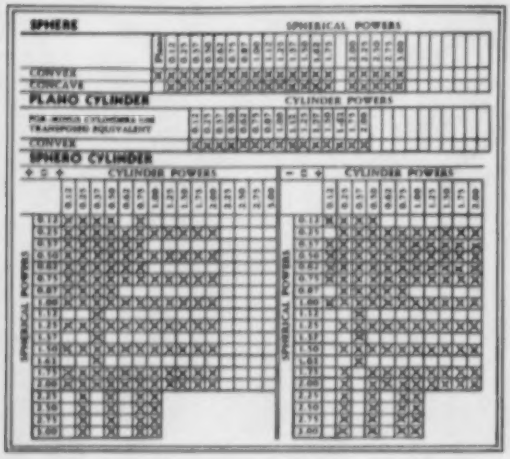

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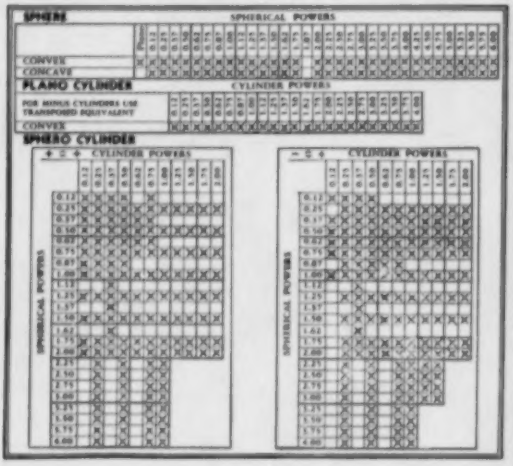

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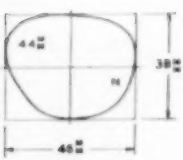

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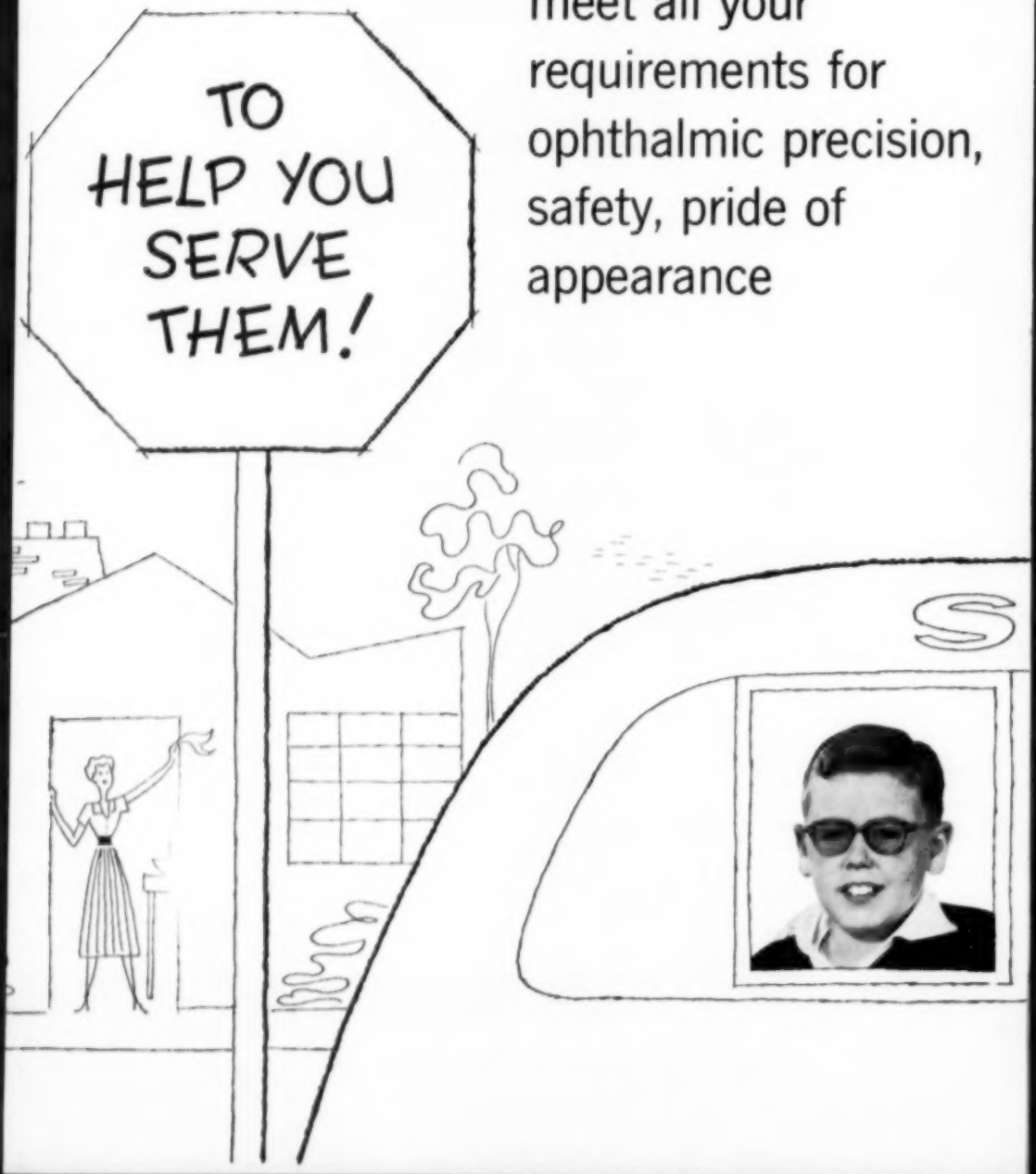

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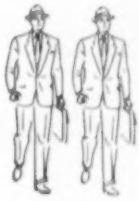

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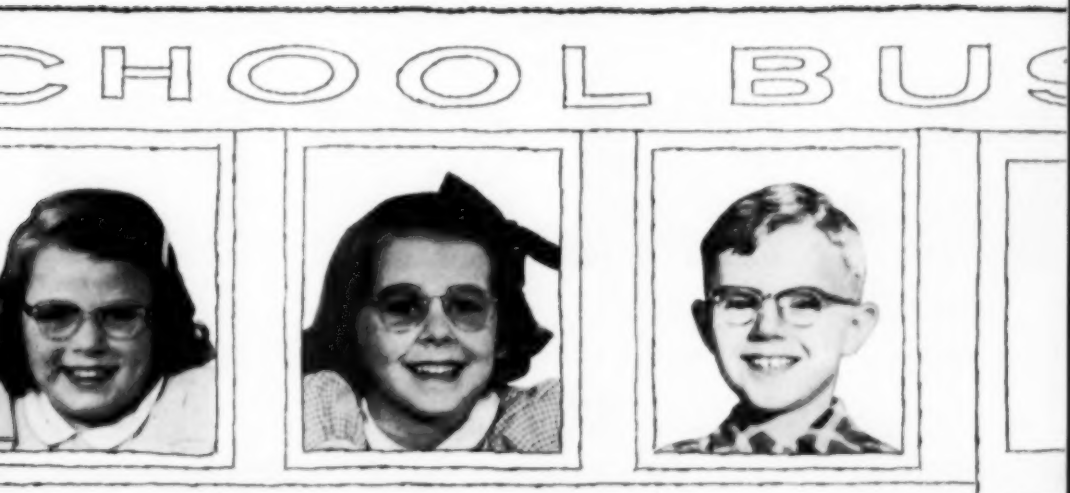

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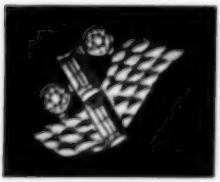

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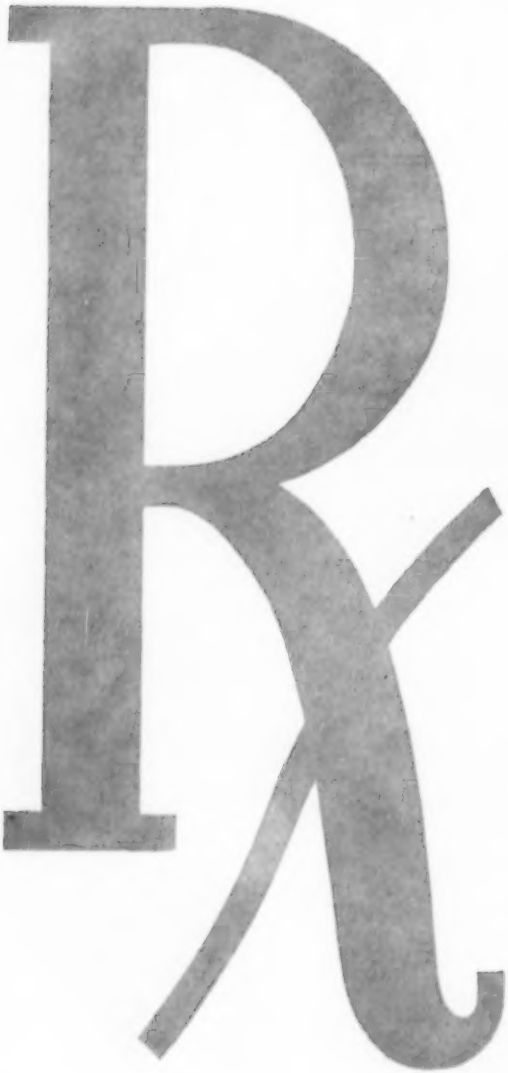

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THE CHARACTERISTICS OF TEN BASIC VISUAL TRAINING PROBLEMS*

Max Schapero†
Los Angeles College of Optometry
Los Angeles, California

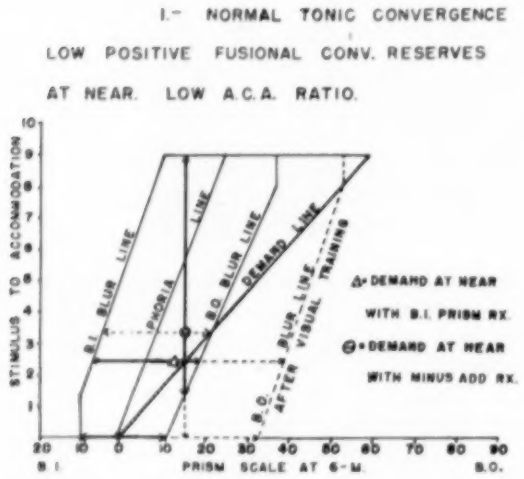
In analysing the various possible motor fusion problems which may occur, it is seen that a great number are caused primarily by the relationship between three visual functions: *tonic convergence* — that convergence induced by the tonicity of the extraocular muscles and responsible for moving the eyes from a position of rest to a fusion free position under conditions of infinity fixation and natural or artificial emmetropia: *fusional convergence* — that vergence independent of reflex association with accommodation which may be induced to obtain and/or maintain clear single binocular vision: and the *ACA ratio*— the amount of convergence change produced by one diopter change in accommodative response.

Tonic convergence may vary in that it may be normal, producing an orthophoric or nearly orthophoric condition at infinity (approximately, between 3 prism diopters exophoria and 3 prism diopters esophoria): it may be low, producing a relatively high exophoric condition at infinity (over 3 prism diopters): or it may be high, producing a relatively high esophoric condition at infinity (over 3 prism diopters). Fusional convergence may vary in that it may be sufficient or insufficient to cope with the demand presented by the phorias at the various fixation distances. The ACA ratio may vary in that it may be normal, between 4 and 6: it may be low, 3 or less: or it may be high, 6 or higher.

When these three functions are combined in the various possible relationships, a number of different visual problems may result. These visual problems may be resolved into ten basic types which will be discussed briefly in this paper.

A first basic problem is one in which tonic convergence is normal, the ACA ratio is low, and the positive fusional convergence reserve

*Read before the second western regional meeting of the American Academy of Optometry, Los Angeles, California, April 16, 1955. For publication in the July, 1955, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
†Optometrist. Member of faculty. Fellow, American Academy of Optometry.



is insufficient to cope with demands at near fixation distances (Figure 1). This problem becomes accentuated with decrease in fixation distance as the positive fusional convergence reserve diminishes, while the infinity condition is adequate. There are a number of reactions that can take place at the nearer fixation distances dependent upon the magnitude of the ACA ratio and the magnitude of the positive fusional convergence reserve. In Figure 1, the reserve at the distance of 40 cm. indicates that the phoria demand is barely met. This would probably result in visual discomfort upon sustained near work and possibly would result in an intermittent or constant exotropia at near. This problem is one of the simplest to correct through visual training techniques whereby the positive fusional convergence reserves are increased.

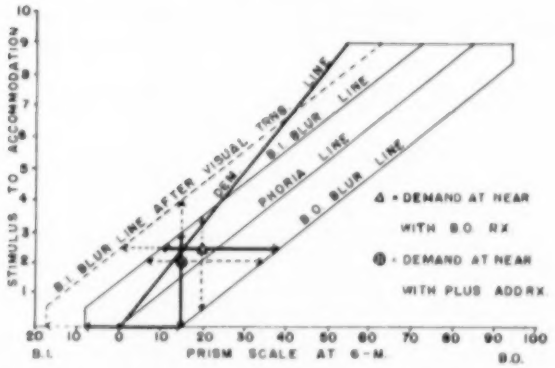
Relief may be given to a patient of this type by the prescription of base-in prism or minus lenses for close work. The latter would only be given when the accommodative amplitude is ample to cope with the increased accommodative demand and when the ACA ratio is of a magnitude to provide enough convergence to make the added accommodative stimulus worthwhile. In Figure 1 the effect of change in demand with the application of base-in prism or minus lenses is demonstrated. The demand now lies in an area where greater reserves are present, this, theoretically at least, resulting in comfort. With successful visual training the demand points remain unchanged but the increased reserves provide a larger "area of comfort."

Since this type of problem is readily amenable to visual training,

it is usually treated in this manner. If the problem is sufficiently intense at closer points and results in an exotropia, then of course sensory fusion will have to be re-established prior to any attempt to build up the positive fusional convergence reserves.

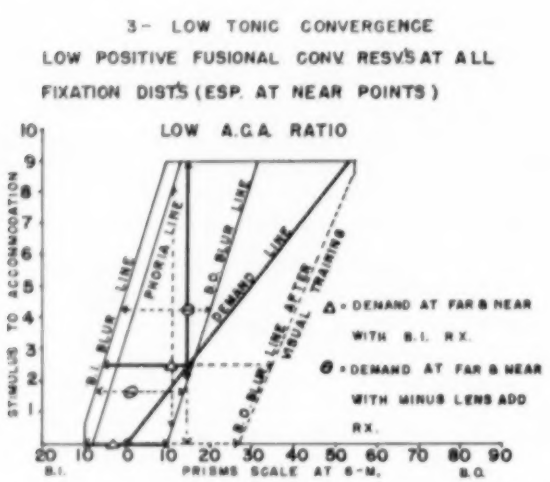
A second basic problem is one in which tonic convergence is normal, the ACA ratio is high, and the negative fusional convergence reserves are inadequate to cope with demands at near fixation distances (Figure 2). In this problem the phoria at infinity is essentially zero with no

2- NORMAL TONIC CONVERGENCE
LOW NEGATIVE FUSIONAL CONV. RESERVES
AT NEAR. HIGH A.C.A. RATIO.



obvious difficulty under distance viewing conditions. At nearer points the situation becomes increasingly severe as the negative fusional convergence reserve diminishes, possibly producing an intermittent or constant esotropia at some near point. In Figure 2 the 40 cm. distance demand is in an area where little reserve is present, this tending to produce discomfort. If visual training were instituted, the aim would be to move the base-in, minus lens acceptance line to the left providing greater reserves and thereby comfort. This problem, however, is not as readily amenable to visual training as was the first and a prescription of plus lenses (or base-out prism) for close work is usually given to place the demands of near distances in an area which will provide greater reserves (See Figure 2).

A third basic problem is one in which tonic convergence is low, the ACA ratio is low, and the positive fusional convergence reserves are low at all fixation distances and especially at near (Figure 3). In this problem a relatively high exophoria is present both at far and near



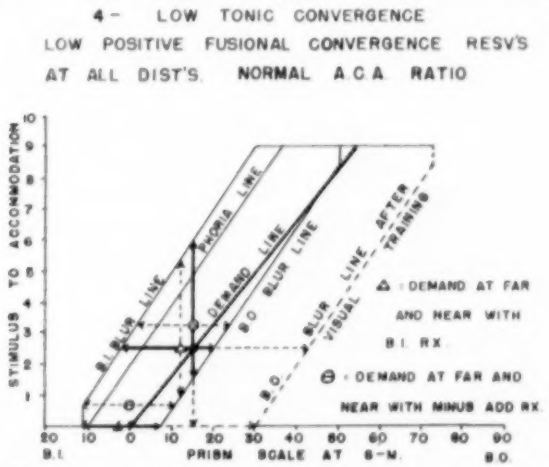
points and, since the ACA ratio is low, the exophoria at the closer points is greater than the exophoria at infinity. In the first two examples, tonic convergence was essentially normal and the trouble at the nearer points was due entirely to the ACA ratio, low in one case and high in the other. In this third variation the exophoria present at infinity presents a problem in itself while the low ACA ratio intensifies the problem at near over that now existing at far.

The reaction here will depend upon the magnitude of the exophoria at infinity, the magnitude of the ACA ratio, and the magnitude of the positive fusional convergence reserve. If the phoria is sufficiently high and the reserve is sufficiently low, the case may prove to be one of intermittent or constant exotropia at all distances or just at near. If not so severe, it may prove to be a phoria condition at all distances with visual discomfort from contending with the high demands. The aim of visual training would be to move the base-out, plus acceptance line to the right to such an extent as to provide adequate reserves for all fixation distances. If such a patient has a tropia then again sensory fusion will have to be given attention prior to this attempt.

A prescription of base-in prism or an over-correction in minus may be given to provide relief providing there is no suppression. The latter alternative would again only be considered if the amplitude of accommodation was sufficient to cope with the increased accommodative demand and the ACA ratio would provide a reasonable amount of accommodative convergence. It may be noted in Figure 3, that the

phoria line is in close approximation to the base-in, minus lens acceptance line. This is characteristic in cases of this type as the exophoria may represent almost the maximum divergence available.

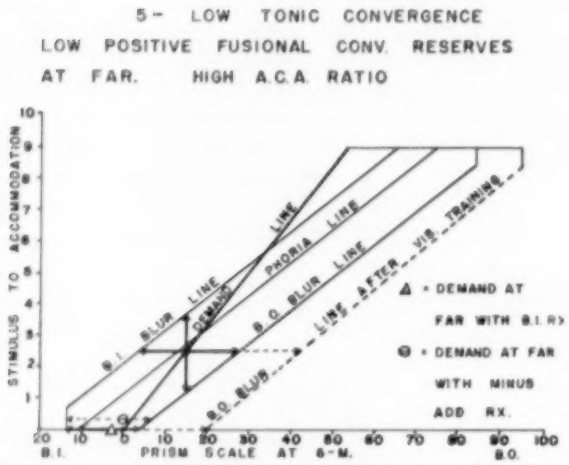
A fourth basic problem is one in which tonic convergence is low, the ACA ratio is normal, and the positive fusional convergence reserves are low at all fixation distances (Figure 4). The source of the trouble


4 - LOW TONIC CONVERGENCE
LOW POSITIVE FUSIONAL CONVERGENCE RESV'S
AT ALL DIST'S. NORMAL A.C.A. RATIO
STIMULUS TO ACCOMMODATION
PHORIA LINE
DEMAND LINE
B.O. BLUR LINE
B.I. BLUR LINE
VISUAL LINE AFTER TRAINING
△ = DEMAND AT FAR AND NEAR WITH B.I. RX.
⊖ = DEMAND AT FAR AND NEAR WITH MINUS ADD RX.
B.I.
PRISM SCALE AT 6-M.
B.O.

lies primarily with tonic convergence in this instance. Approximately the same amount of exophoria is present at all fixation distances, the ACA ratio now being between four and six, and thus the extent of the difficulty would remain approximately the same. As in the third variation, this type may also prove to be one of constant or intermittent exotropia.

Relief may be afforded by visual training, moving the base-out, plus acceptance line to the right to provide sufficient reserves to cope with the exophoria or by the prescription of base-in prism or an over-correction in minus lenses.

A fifth basic problem is one in which tonic convergence is low, the ACA ratio is high, and the positive fusional convergence reserve at far is low, with possibly adequate reserves at near (Figure 5). In this type the high ACA ratio assists in reducing the amount of exophoria at near fixation distances over that present at infinity by producing a relatively large amount of accommodative convergence. This in turn diminishes the intensity of the problem at closer points and might even reverse the condition by producing an esophoria at near. The purpose of visual training here would be to increase the positive fusional

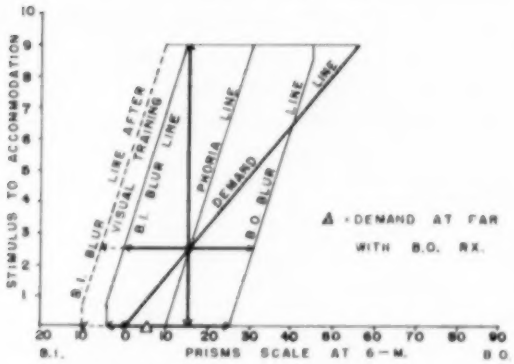


convergence reserve with the infinity condition in mind. Likely there would be no problem at near points, the low tonic convergence now providing a cushion for the high ACA ratio. If a problem is present at the near point due to an esophoria, then the training would be to increase negative fusional convergence reserves as well. Base-in prism or an over-correction in minus might be given but primarily for the infinity situation.

A sixth basic problem is one in which tonic convergence is high, the ACA ratio is low, and the negative fusional convergence reserve at infinity is low, with probably no difficulty at near points (Figure 6). The situation present at near will vary with the amount of esophoria present at infinity and the magnitude of the ACA ratio. Here the low ACA ratio serves to reduce or eliminate the esophoric demand at near fixation distances, the esophoria at far cushioning the effects of the low ACA ratio. Regarding corrective visual training, it would be primarily to increase negative fusional convergence reserves. The type of training indicated for near points would again vary with the magnitude of the esophoria at infinity and the ACA ratio. Base-out prism might be prescribed for use at infinity.

A seventh basic problem is one in which tonic convergence is high, the ACA ratio is normal, and the negative fusional convergence reserves are low at all fixation distances (Figure 7). In this type there is again an extension of the far point situation to the near points, the ACA ratio being between four and six, and thus essentially the same demand on negative fusional convergence will be present at all fixation

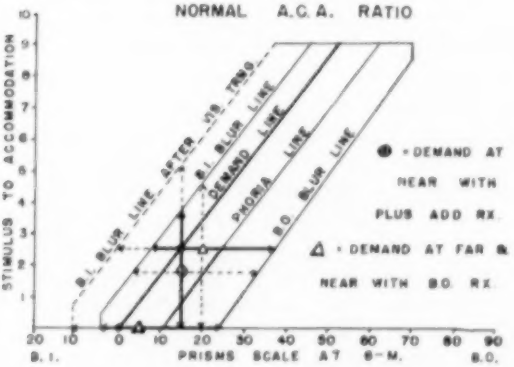
6 - HIGH TONIC CONVERGENCE
LOW NEGATIVE FUSIONAL CONV. RESERVES
AT FAR. LOW A.C.A. RATIO



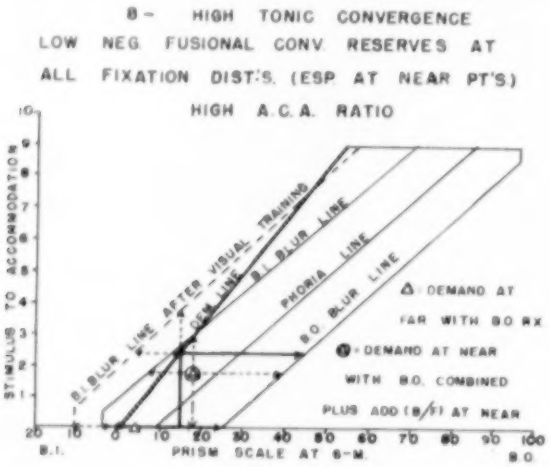
distances. This case might prove to be a constant or intermittent esotropia, if the tonic convergence is very high. Successful visual training would move the base-in. minus lens acceptance line to the left to provide adequate reserves. A prescription for relief would be one of base-out prism to be worn at all distances or possibly of base-out prism combined with a plus add for close work.

An eighth basic problem is one in which tonic convergence is

7 - HIGH TONIC CONVERGENCE
LOW NEGATIVE FUSIONAL CONV. RESERVES
AT ALL FIXATION DISTANCES
NORMAL A.C.A. RATIO

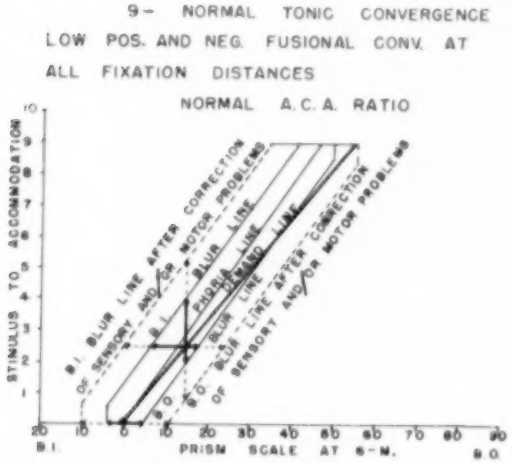

STIMULUS TO ACCOMMODATION
B.I. BLUR LINE AFTER VIS. TRNG.
B.I. BLUR LINE
DEMAND LINE
PHORIA LINE
B.O. BLUR LINE
● = DEMAND AT NEAR WITH PLUS ADD RX.
Δ = DEMAND AT FAR & NEAR WITH B.O. RX.
B.I.
PRISMS SCALE AT 6 - M.
B.O.

high, the ACA ratio is high, and the negative fusional convergence reserves are low at all fixation distances and especially at near points (Figure 8). The ACA ratio here intensifies the problem by increasing the esophoric demands, one diopter change in accommodation introducing six or more prism diopters of convergence. This condition could


8 – HIGH TONIC CONVERGENCE
LOW NEG. FUSIONAL CONV. RESERVES AT
ALL FIXATION DIST'S. (ESP AT NEAR PT'S)
HIGH A.C.A. RATIO
STIMULUS TO ACCOMMODATION
B.I. BLUR LINE AFTER VISUAL TRAINING
B.I. BLUR LINE
PHORIA LINE
B.O. BLUR LINE
Δ = DEMAND AT FAR WITH B.O. Rx
● = DEMAND AT NEAR WITH B.O. COMBINED PLUS ADD (B/I) AT NEAR
B.I.
PRISM SCALE AT 6-M.
B.O.

easily result in constant esotropia at near and also a constant or intermittent esotropia at far. Visual training would be instituted to increase the negative fusional convergence reserve. The prescription of lenses and prism to provide complete relief may still have to be given even if visual training is instituted, since its success in this instance would probably be limited. Base-out prism could be prescribed for all fixation distances, possibly in combination with a plus add for near work. If esotropia is present then sensory fusion, as mentioned previously, will have to be attended to prior to attempts to increase the negative fusional convergence reserves and/or the prescription of prism and/or lenses.

A ninth basic problem is one in which tonic convergence is essentially normal, the ACA ratio is essentially normal, and both the positive and negative fusional convergence findings are low (Figure 9). The characteristic picture of this variation is of a very narrow zone of clear single binocular vision for all fixation distances. This case may not prove to be a visual training problem as there would be no particular demand on fusional convergence. However, there is often an associated sensory fusion problem which causes the poor motor responses, as uncorrected refractive errors or aniseikonia. The proper prescription may


9- NORMAL TONIC CONVERGENCE
LOW POS. AND NEG. FUSIONAL CONV. AT
ALL FIXATION DISTANCES
NORMAL A.C.A. RATIO
STIMULUS TO ACCOMMODATION
B.I. BLUR LINE AFTER CORRECTION OF SENSORY AND/OR MOTOR PROBLEMS
PHORIA LINE
BLUR LINE
B.O. BLUR LINE AFTER CORRECTION OF SENSORY AND/OR MOTOR PROBLEMS
B.I.
PRISM SCALE AT 6-M.
B.O.

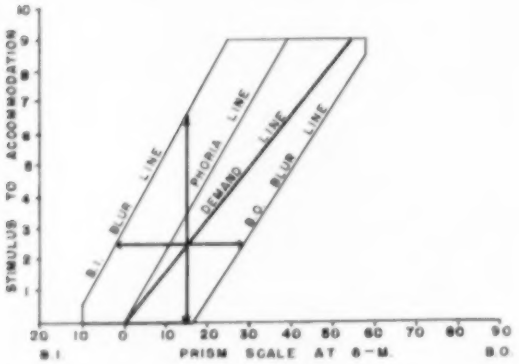
relieve the sensory fusion problem and the reserves may increase without visual training.

Another cause for a picture of this type is uncorrected vertical phorias. The difficulty in overcoming the vertical phoria demand in turn reduces the efficiency of the lateral motor fusion skills. A further possibility is that the motor fusion findings are low because of disuse. Since there is no particular demand on fusional convergence, the phorias at far and near being essentially orthophoric, the presentation of fusional convergence demands in the testing situations would not produce large quantitative responses. Some believe that a case of this type indicates a systemic disturbance.

A tenth possible problem is one in which tonic convergence appears normal, the ACA ratio appears normal, and the fusional convergence reserves appear normal (Figure 10). On occasion a case of this type is encountered where visual symptoms are present and one may be at a loss to find the cause on the basis of the findings. As in the previous case, there are a number of possible causes for this situation. The symptoms might be psychosomatic in nature or due to some systemic or ocular pathology (this possibility of course should be investigated in all cases). Other possibilities are that aniseikonia, uncorrected or improperly corrected refractive errors or vertical phorias are responsible.

Also the phorias may be invalid, as for example, the presence of a relatively high exophoria disguised by positive fusional convergence movements during the phoria testing. Often this will happen, and even an apparent esophoria with low base-in ductions may be obtained.

10— APPARENTLY NORMAL TONIC CONVERGENCE, NORMAL FUSIONAL CONV. RESERVES, & NORMAL A.C.A. RATIO.



all due to the persistence of positive fusional convergence in the phoria tests and the reluctance to use negative fusional convergence in the base-in tests. A careful cover test will reveal the basic problem here, that is, a relatively high exophoria.

Another aspect of a disguised motor fusion disturbance is the inability to maintain the apparently adequate findings. Thus if the same test, as the base-out duction, were repeated a number of times, it might be found that the findings gradually drop upon each succeeding trial. It may now be concluded that there is a fatigue factor involved, with the apparently normal reserves unable to be sustained under continued stress.

A method of determining whether symptoms are due to attempts to maintain binocular vision is the occlusion of one eye for a relatively long period of time. If the symptoms are relieved under monocular conditions, it would give evidence that binocular vision is in fact the cause.

In summary, it may be seen that the relationship between tonic convergence, fusional convergence, and the ACA ratio will produce various types of visual problems resolvable into ten basic types. The realization of these relationships will enable a greater understanding as to the underlying cause of these problems and the measures to be taken, both from the standpoint of visual training and lens prescriptions, to correct them.

EVOLUTION AND THE HUMAN EYE*

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The purpose of this paper is to attempt to summarize portions of the literature on evolution showing a theoretical means by which the development of the eyes could be followed from the lowest invertebrate through the highest vertebrate. Six main topics will be reviewed: First, two theories of evolution, one widely accepted and the other not so widely accepted; second, a method by which characteristics can be and probably are transferred or inherited by any living organism; third, several means of altering inherited characteristics; fourth, the probable chronological order of appearance of animals; fifth, a discussion of the parallel that seems to exist between the embryological development of man and his vertebrate predecessors; and sixth, a study of some of the evolutionary changes of the eyes. In this final part will be covered the changes which some of the various faculties, such as, accommodation, eye movements, binocular vision, and color vision have made in the process of evolving from the lowest vertebrate up to man.

Practically all contemporary biologists believe in organic evolution, that is, that species of animals now living have evolved from other species (Hegner). Carter states: "Man is an animal, and, however great his present state differs from that of the rest of the animal kingdom, we must accept that he arose from subhuman ancestors by a process of evolution." Simpson adds this comment: "It is however a gross misrepresentation to say that he is just an accident or is nothing but an animal."

Evolution may be defined as a series of changes in which the nature of each step depends on what has gone before (Shull). Therefore, it seems pertinent that some consideration of an accepted theory of evolution should be made to show the means by which man's present structure has been achieved.

In 1859 Darwin published, "The Origin of Species," in which he set forth his theory of evolution. The basic principle underlying this theory is that of "natural selection." This theory, in a slightly modified form, is the one which is accepted almost universally today (Carter, Moody, Dolzhansky and Huxley).

*Read before the annual meeting of the American Academy of Optometry, Toronto, Ontario, Canada, December 12, 1954. For publication in the July, 1955, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
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Another theory, that of Lamarck, was introduced in 1809. This basically is that of inheriting "acquired characteristics" but since there are facts which show that it does not always operate it is not an accepted one (Dolzhansky and Huxley).

"Evolution may be pictured as a series of changes which are more or less permanent, continuing that is, until other changes replace them" (Shull). These would be what we commonly know as hereditary changes. The most important thing to know about hereditary changes is how they may occur and why they are permanent.

The parts of the reproductive cell of all living organisms which carry the hereditary characteristics are called chromosomes (Morgan, Shull, and Dolzhansky). These are visible with a microscope and are contained in the nucleus of the cells. The elements in the chromosomes which maintain and carry the individual characteristics are called genes. The characteristics carried by these genes may be considered as dominant or recessive depending on the positiveness with which they transmit their factors. It is possible to calculate the frequency of appearance of these factors to an amazingly accurate degree.

As stated before, the skeletal framework to which the genes are attached is called a chromosome (Morgan, Shull and Moody). The arrangement of the genes along the chromosomes may be the same through a large number of generations and duplication of the genes and chromosomes is dependent on the process of reproduction. If the genes or chromosomes fail to reproduce themselves or if there is a change in them so as to give rise to a variation in the structure or arrangement of the resultant genes, it is called a mutation (Shull and Huxley). This mutation or variation is what may lead to changes which are permanent and may be passed on to the next generation. According to Darwin's theory, if this mutation causes a structural change in the organism which would make it better able to survive in its environment, it would be better enabled to live to pass on this characteristic. The changes which the chromosomes and genes make to bring about a different gene arrangement were described by Mendel in 1865.

There are three major means by which the pattern of genes may be altered: namely, sudden temperature change, the action of chemical agents, and radiation (Shull, Moody, and Dolzhansky). The changes are usually the result of the breaking and growing back together of the chromosomes, thus leading to a different gene arrangement on the resultant chromosomes, or of the altering or destruction of the genes themselves (Moody).

The result of mutations caused by the shock of sudden temperature

change have been observed with the microscope in the drosophila fly.

Also there has been a great deal of research and study done observing organisms which have been introduced to chemical agents. In some cases there were sixteen times as many mutations as in normal organisms (Shull). This can and does take on some very practical aspects in our current everyday life. There has been demonstrated a reaction of a chemical agent on the gene which restrains the growth of tissue. A popular theory is that one of the causes of cancer could very well be the result of the action of some chemical agent on this gene in the tissue of higher animals. The effects of such a change would probably lead to abnormal growth in the affected area.

By far the largest cause of mutations is radiation and this can be demonstrated by observing the effects of X-ray on plants and animals. A real factor to be considered is the effects of this cause of mutation on man from the atom and hydrogen bombs. It seems that all men investigating the problem agree that it would be more confortable if the effects of radiation on genes did not have to be faced.

Shull has this to say: "Because of the known production of lethal or injurious mutations by radiation of various types, concern has been expressed as to the effect of the explosion of atomic bombs or even the industrial use and possible leakage of nuclear energy on the direction of human evolution. It is assumed that man is as subject to radiation induced mutations as are other animals and that by and large mutations will be detrimental. It will be some time before direct evidence of these points can be obtained from human populations that have been exposed to atomic bombs. Possibly no actual proof of such effects can ever be obtained in that way. Accepting, however, the likelihood that harmful mutations are so produced, some publicits have expressed the fear that as an extreme consequence the human might be destroyed. Short of this dire result, they foresee the occurrence of many monsters, unless men mend their ways before it is too late."

A later source of information (Hutchinson) states that since the atom bomb fell on Hiroshima there have been over 30,000 births in that city. One out of every seven of these births has been abnormal, the deformities ranging from bone and muscle developmental anomalies to an absence of brains and eyes.

We are fortunate in having recorded for us the evolutionary steps which plants and animals have taken up to our present stage of development. It was about 500 million years ago that animal life reached the point when it produced hard parts capable of being preserved as fossils (Colbert). About the earliest ones we know are the arthropods

which we know as trilobites. It is easy to find these imbedded in limestone and in creek beds.

Colbert gives a very nice outline showing the approximate chronological order of appearance of animals. He estimates that about 2,000 million years ago the first life appeared on this earth probably starting with the single celled organisms. Some time later appeared the lowest invertebrates with some higher invertebrates evolving around 500 million years ago. The first vertebrates existed around 400 million years ago and were aquatic as were the invertebrates. These would be what we know today as the fish family.

About 300 million years ago some of these fish evolved to the point where they had legs and lungs and could leave water for at least a part of the time. Thus, we had the beginning of the age of amphibia. This extended to about 200 million years ago and began the reptile age which was the longest in terms of length of time which any group of animals dominated the earth.

The first mammal appeared about 70 million years ago and the larger reptiles disappeared around that time. Primates, the family to which man belongs had its origin about 50 million years ago.

Man has been present on the earth less than one million years so his age is very young.

One of the invertebrates bearing an almost direct relationship with the lower vertebrates is the amphioxus. Two of the structures that this animal has in common with the vertebrates is a central nervous system and gill arches. It is interesting to note the derivitives of these gill arches as subsequent higher orders of vertebrates are studied (Setterfield and Romer).

The first order of vertebrates to be compared was the fish. In comparing these gill arches as if they were numbered from one to nine as they appear in the amphioxus, we can draw the following conclusions. Number one has changed to form the upper and lower jaw, number two the hyoid and hyomandibular cartilage and number three, four, five, six, and seven remain as the present gill arches which are found in the fish. Eight and nine have disappeared.

The next order of vertebrates to be compared is the amphibia and may be represented by the frog. In this animal none of the arches are open for breathing except in the tadpole stage. As in the fish, the first gill arch forms the jawbone, number two has evolved into the ear. Gill arches three, four, five, six and seven are found very much reduced in size and form the cavity which leads to the trachea.

In the reptile a still further evolutionary change can be found.

The lower jaw is further developed, the inner ear has enlarged and is more complex. Arches, three, four, five, and seven have evolved to form the trachea but never open to function for breathing, and six becomes the epiglottis.

In the mammal there is a still further change. Number one has receded to form the inner ear along with a part of number two. The balance of the second gill arch along with three is used to form the larynx. Four and five sprout out but loose their connections with the throat and remain in the neck as glands of internal secretion. Number six forms the epiglottis and seven a series of tracheal rings.

Five gill arches develop in the early embryo of man as they have developed in his predecessors for hundreds of millions of years. However, in man they never open or function for breathing. The stages in the development of these gill arches can be seen and followed from the beginning of the growth of the human embryo up to the point where it acquires all of its organs. These changes paint a very unique picture paralleling the embryological development of man with the evolutionary changes which the gill arches have made in the other vertebrates (Moody).

The reaction of organisms to light is not confined to animals; plants and plant cells also react to light. Neither is it confined to larger animals; even single celled animals such as the amoeba and paramecium react to light by traveling towards or away from it or by changing shape (Duke Elder).

Light sensitive cells may be found acting individually in some of the lower orders of worms and molluscs. An example of an animal making use of its individual light sensitive cells is the mollusc closing its shell in response to light. They have a nucleus, and fibrillar structure and are usually associated with a light sensitive pigment as are our own rods and cones. These cells are scattered through the ectoderm of these animals and assume various forms and shapes (Duke Elder).

In still other types of shell-fish can be observed the next step to which the invertebrate eye has evolved. This is represented by light cells grouped together and acting collectively as a simple eye.

Some arthropods have still larger numbers of these cells grouped together within an evagination of the surface ectoderm, thus forming the beginning of a compound eye.

In the crayfish and insects can be found the compound eye, which is the ultimate achievement of the eye in invertebrates. It has been formed by the complete evagination of the surface ectoderm forming a sphere containing the light cells with an optical apparatus in front to

focus the image. These eyes are complete in almost every respect with their functionally and structurally associated elements (Duke Elder).

Thus far, we have a compound eye which has evolved by way of single cells acting individually and groups of cells acting collectively to a very large group of cells which have evaginated to form a sphere containing the light cells. The one thing that sets this invertebrate eye apart from the vertebrate is that the eye is formed by the evagination of the surface ectoderm. In the vertebrates the formation of the eye is quite similar except that the evagination which takes place to form the eyeball does not take place from the outside but from the inner neural layer of the animal. Thus the eye instead of forming from the outside in, forms from the inside and the envelope which forms the eye has to migrate to the surface in order to reach the light (Duke Elder and de Beer).

The most common belief is that as the envelope reaches the surface, the ectoderm forms the cornea and lens, while the inner layers form the lids, lachrymal apparatus, sclera, extra-ocular muscles, and the rest of the eye orbit. It seems significant to point out that all vertebrate eyes follow this plan in their development (Duke Elder and de Beer).

Many invertebrates including some worms, almost all arthropods, and even some molluscs have highly developed eyes, some approaching our own in degree of organization. In the lower vertebrates even the humblest of fishes have already evolved paired eyes essentially similar to those of man. The embryology of the vertebrate eye indicates that there could have been no complete eye until the chordates had evolved an internal tubular central neural system (Romer).

In making a search for literature relative to the evolution of the eye it seemed that the most authoritative and complete work on the subject is Walls' book, "The Vertebrate Eye." Consequently the final part of this paper will be, to a large extent, the conclusions which have been reached, after reading this excellent work.

The study of the evolution of the vertebrate eye seems best begun with the statement which Walls quotes from the great German anatomist, Froeriep. He likened the sudden appearance of the vertebrate eye in evolution to the birth of Athena, fully grown and fully armed from the brow of Zeus.

This is closer to the truth than may be realized. The observation of the eye of a lamprey which has the simplest nondegenerate vertebrate eye reveals an eye complete with a mechanism for accommodation, lens, cornea, retina with rods and cones and six external ocular muscles,

thus making it complete in almost every respect (Walls).

Several authors in giving the steps in the evolutionary development from the lower vertebrates up to man, state that there has been a gradual shift to frontal placement of the two eyes. This is not necessarily so. The shift to frontality has been achieved in fishes and in birds as well as in man. Walls points out that frontality was best suited to and usually was possessed by animals which were hunters. This served them better when pursuing another animal. On the other hand, if the eyes were to the sides of the head, it would make it possible for animals to see to the sides as well as behind. This is the arrangement which is usually possessed by animals which are preyed upon (Walls).

The evolution of the mechanism of accommodation seems to present about the most clear cut steps which the eyes have taken to approach those of man.

In the cyclostome fishes or the lampreys accommodation is accomplished by a change in the shape of the cornea and the eye itself. The lens of the eye is spherical and does not change position or shape but remains in contact with the cornea. The lamprey is normally about 8.00 D. myopic and when accommodation takes place, the eye becomes emmetropic or even hypermetropic to a fairly high degree (Walls).

The elasmobranch and teleost fishes are a higher order and show a definite change from the lamprey. In these animals accommodation is brought about by the movement of the crystalline lens forward and backward from the cornea by a ciliary muscle but it does not change shape (de Beer). Such eyes are usually hypermetropic with a high degree of accommodation possible (Walls). The higher fish groups show the same method of accommodation.

In the amphibia is found the first emergence of animals from water. The thing that is accomplished as far as the eye is concerned by this event is that it brings into play for the first time the full effect of the cornea as a part of the refracting mechanism. Accommodation in the amphibia takes place the same as in fishes. Even though the lens is in position to change shape and has suspensory ligaments attached almost identically to those in the eyes of the mammal group, it still moves forward and backward to change the focus of the eye-ball (de Beer). Most amphibia have less than 5.00 D. of accommodation and are approximately emmetropic (Walls).

In the reptile, which is the next order above the amphibia, the mechanism of accommodation has again made a definite change. It may also be noted that this is the first group of animals studied in which

the lens changes shape to produce accommodation. This is caused by a sphincter muscle which circles the lens and when contracted, squeezes it and forces it to change focus (de Beer). The range of accommodation accomplished in this manner is sometimes over 30.00 D. (Walls).

Birds are essentially the same as reptiles in manner of accommodation and the range may be over 40.00 D. (Duke Elder). Their visual acuity is sometimes eight times as sensitive as that of man.

Mammals, or the order to which man belongs, show a still higher step to which the mechanism of accommodation has evolved. It is brought about by the contraction of the ciliary muscle which releases the tension on the suspensory ligaments. These ligaments are attached to the margin of the capsule of the crystalline lens so that when the tension is released, the elasticity of the capsule forces the lens to change shape and thus accommodate. This is the process by which man's accommodation takes place (de Beer). An interesting observation also is that man has the highest accommodation amplitude of all the mammals (Walls).

The factor which seems to determine the extent of the eye movements in vertebrates is the development of the fovea centralis. If no fovea centralis were present, there would be no need for an eye to turn in order to allow the image to fall on a point of high discrimination. Consequently, even though the six extra-ocular muscles are present in all vertebrates, there is little or no use of them in many of the lower orders (Duke Elder).

The study of fishes indicates that the original primitive function of the eye muscles was not to aim the eye at objects. The movements which they exhibit are only reflex and involuntary. There seems to be an absence of a fovea in most fish thus supporting the reason for the absence of eye movements (Walls).

Amphibia seem to be almost as devoid of eye movements as fish. The only ones they are known to perform are elevation and retraction. Only a few have an area centralis (Walls).

Reptiles show a distinct step in the evolution of eye movements and the development of a fovea in that almost all species have a good foveal area and are able to perform eye movements spontaneously. Consequently, reptiles have a need for and make use of the external ocular muscles. The lateral movements are coordinate for binocular observation but vertical movements are made independently by the two eyes. In other words reptiles do not have truly conjugate eye movements (Walls).

Many birds have two foveas in each eye, one centrally located which

is used when looking to the side or back and a temporal one which is used to gain fusion for binocular vision (Romer and Duke Elder). Such eyes are usually very large for the socket so that there is a very limited ability to turn them. This deficiency is more than made up for though by the flexibility of the neck (Walls).

Eye movements in mammals range from almost no motility such as is found in the rabbit, which has no fovea, to the maximum which is found in man. The movements, when they are possible, are always conjugate. This factor seems to be another definite step in the evolution of the eye and seems to be linked with the partial decussation of the optic nerve fibers at the chiasma which takes place in mammals as compared to the total cross over of the fibers which is present in the lower vertebrates (de Beer). There seems to be a definite link between the limit of voluntary eye movements and visual acuity and the acuity seems to go hand in hand with the intelligence (Walls).

As important visual characteristic which almost all vertebrates possess to some degree is the overlapping of the monocular fields. This would naturally be controlled by the degree of frontality which the animal possesses. This presence of a binocular field has been achieved in almost all of the orders of vertebrates and is not limited to higher vertebrates. It does seem apparent though that the succeeding higher orders of animals have wider binocular fields. An interesting fact, too, is that in some animals the monocular fields overlap behind as well as in front (Romer and Walls).

Many authors discuss a third (pineal) eye which faced upwards in the middle of the skull roof and seems to have been an important visual sense organ in primative vertebrates. This third eye has gradually disappeared and today is found only in a few surviving lizards. It is complete with lens and retina but the extent of its use is questionable. We might speculate as to where this third monocular field might fit into the binocular picture. In man this primitive eye is present only as a small stalked red body, the pineal body, lying buried beneath the hemispheres of the brain with function not definitely known (Romer, Walls and Duke Elder).

With the presence of a binocular field one might assume that binocular vision is also present with singleness of perception, fusion, and even stereopsis. But is this really true? This seems possible in only a few of the vertebrates before the reptiles because the limited movement of the muscles did not make it possible for the animal to aim the eyes so that a single image could fall on corresponding retinal points. In the higher animals such as reptiles and birds this positioning of the eyes

is possible and good binocular vision is probable (Walls).

As was stated before there is one major difference between the mammals and the lower vertebrates and that is the partial decussation of the optic nerve fibers at the chiasma (Romer) of the mammals. A large percentage of authorities have seen in this the essential basis of fusion and stereopsis. The law of Newton-Muller and Gudden gives the number of uncrossed fibers as closely proportional to the degree of frontality. In man it is just about 50-50 with the impression falling on the right side of each eye going to the right side of the brain and the left ones to the left. This makes it possible for images falling on corresponding points of the two retinas to stimulate single points in the visual cortex. This is probably the reason why it is difficult for us to observe centrally, two, different, unfusable, or nearly so, images with the two eyes independently without experiencing discomfort (Walls).

The development of the essentials for color vision is somewhat the same as the evolution of frontality in the various orders of vertebrates in that it is not possessed by higher animals alone but is achieved in most of the lower orders as well. The one thing that seems necessary is a good mechanism of accommodation. The reason for this is the need for good visual acuity or a means of bringing the color in good focus on the retina. Another thing which is needed for color discrimination is the presence of a retina which is rich in cones, since they are the visual cells that any animal needs to interpret colors. The conclusion that could be arrived at then, is that any animal which possesses both of these characteristics could possibly have color vision. Since cones are possessed by some of the animals in almost every order of vertebrates from the lowest to the highest they may almost be eliminated as a controlling factor (Walls). One author makes the statement that the groups of vertebrates which possess the best color vision are the very ones which have evolved excellent mechanisms of accommodation (Walls).

Another author rates the ability of the lower vertebrates to differentiate colors as being purely a manifestation of vision on a scotopic basis or on a level with the totally color-blind human (Duke Elder). It is difficult to say what the final answer to this will be.

In conclusion there are a few statements which may be made relevant to the evolution of the eyes. Those of man do not necessarily have all of the advantages which have been gained in some of the lower vertebrates. Actually man has lost several of them through the process of evolution. His accommodation is not as efficient and visual acuity

is not nearly so good as that attained by birds. Man's eye movements are better and the partial decussation of nerve fibers at the chiasma may have given him an advantage for binocular vision but even this is not definitely known. The one factor which does set man aside though and gives him a definite advantage over his predecessors is his intelligence. This seems to parallel the development and increase in size of the cerebral hemisphere as they evolve through the subsequent higher orders of vertebrates. But have man's eyes actually reached their peak of development? When studying the lower vertebrates we compare animals which are the results of millions of years of evolution, while with man the results which are studied are of a much shorter duration. Time will tell what his ultimate achievement will be.

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AN EVALUATION OF THE BIOLOGICAL AND NEARWORK CONCEPTS OF MYOPIA DEVELOPMENT*

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Pullman, Washington

The separation and evaluation of the contributions of heredity and environment to the development of behavioral and structural variation is an extremely difficult task and one which has correctly occupied a position of primary importance in the biological and behavioral sciences. Psychologists, for example, have pursued the question of the contributions of heredity and environment to differences in intelligence for the last forty or fifty years and have arrived at two generally accepted conclusions. First, heredity plays the major role underlying differences in intelligence with estimates of its contribution ranging between fifty and seventy-five per cent of the total variation. Secondly, heredity is conceived of as setting certain limits within which the environment may cause differences between individuals. Thus, for example, in terms of I.Q. an individual may have an hereditary endowment which gives him the possibility of having an I.Q. ranging between 100 and 120. Where he will fall within this range will depend upon the type of environment to which he is exposed: the better the environment, the higher the I.Q., other things being equal.

These conclusions are based upon a number of experiments of the foster children and co-twin control type. In the foster children experiment, children of unrelated hereditary are raised as foster children in a home with the blood children of the foster parents. If environment were the all important variable, the foster children should show the same I.Q. as the blood children, since the environment would be as similar as it is possible to make it, while the heredity is different. The opposite relationship is obtained in studies involving identical twins. In these studies identical twins, who are considered to have exactly the same hereditary characteristics since they develop from the same zygote, are placed in different environments and their I.Q.'s are compared after the environmental influences have had a chance to exert their effects. Such studies consistently demonstrate that the I.Q.'s of identical twins reared in entirely different environments are more similar than those of

*Submitted on October 21, 1954, for publication in the July, 1955, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
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foster and blood children reared in the same environment. While these experiments support the conclusion that heredity plays a larger role than environment in producing differences between individuals, the interpretation of the relative importance is dependent upon the judgment of the investigator since the experiments do not yield such information.

The second conclusion concerning the range and the influence of environment is based on studies of the effects of extremely restricted, average, and superior environments on unselected subjects. It should be emphasized that these results cannot be considered apart from the techniques of measuring I.Q. If intelligence is defined as an innate ability with the usual connotation of hereditary determination and resistance to environmental influences, then, by definition, it is entirely dependent upon heredity and we have no means of measuring this ability directly, since all that we can measure is the present achievement of a subject in a standardized situation. With the utmost degree of simplification we might postulate that the score which an individual makes in this standardized situation is a function of his innate ability, or intelligence, the type of environment to which he has been exposed, and his level of motivation in the test situation and during his exposure to the environment. Only if the latter two are constant for all subjects, can we say that we have a measure of the innate ability of a subject. Thus the score which an individual makes on an intelligence test is subject to environmental influence, so that it is meaningful to speak of the influence of the environment on the I.Q. or test score, but not upon the innate ability called intelligence. The latter is not meaningful because we have no technique for determining this effect.

This long digression from the topic of hereditary and environmental concepts of the development of myopia has been made because the two situations are similar, and point the way to the types of experiments which can be performed to answer the question of the relationship between the two. It would be possible to place children of unselected heredity in the same environmental situation with children of known heredity, and submit them to the same degree of near work, thereby determining the influence of the environment. The more desirable approach would be to submit one member of a pair of identical twins to an environment of a great amount of near work and the other to an environment of little near work, repeating this over as many twins as possible. Since these experiments have not been carried out on a definite scale, we must look for other evidence which would permit us to draw some conclusions as to the importance of heredity and environment in the development of myopia.

For the purposes of this paper the biologic theory which will be considered is that formulated by Steiger[7] together with some of the more common modifications suggested by his followers. In essence, this theory holds that the refractive parts of the eye such as corneal radius, lens curvature, axial length, etc., may be considered to be distributed in a chance manner such that a large number of measures made on unselected subjects would form a normal distribution when plotted. Or more correctly, since the distribution of a large number of measures of certain optical elements form distributions which are similar to binomial or normal distributions, they may be considered to vary by chance. This distinction is important since the second statement must necessarily precede the first, even though the first may be stated in the form of an hypothesis when it is based upon knowledge concerning the distribution of other physical measures. Further, if these elements which contribute to the total refraction are distributed according to chance and occur by chance, we may assume that they occur by chance combination in any one individual according to the Mendelian law of the chance grouping of hereditary characteristics., If these conditions are maintained we might expect to find a normal distribution of total refraction among a large number of unselected subjects. Since the total refraction curve for adults is not the same as that for children in terms of the parameters of the distribution, especially the mean and standard deviation, there is a change in refraction which occurs as the child grows older. If we assume as some investigators such as Kettesy[4] and Stansbury[6] do, that nurture has no influence upon refractive changes, we must assume that the later changes are determined at conception.

This statement of Steiger's biological theory permits its evaluation (a) in terms of the applicability of the normal curve and the concept of chance to the refractive parts of the eye, and to the total refraction of the eye in terms of the independent grouping of these variables to give rise to the total refraction of the eye, and (b) in terms of the growth characteristics of the total refraction of the eye.

Before discussing these assumptions, we should consider the measure of total refraction most commonly used by adherents to Steiger's theory. The static retinoscopic finding is a measure of the total refraction under certain specified or standard conditions and is comparable to the intelligence test score in that there is nothing in the measure itself that can indicate to the investigator that it is entirely, partly, or not at all due to the influence of heredity. In other words, it is a measure of the present state of the subject and reflects the results of any influences which may have operated on the eye. The interpretation that this

measure is a measure of the hereditary influences is strictly an assumption, and there is no proof that can be brought to support this assumption at the present time. To say that since the static retinoscopic findings are normally distributed, they represent measures of hereditary factors is equivalent to saying that diet plays no role in determining the weight of individuals, since the weights of a group of individuals form a normal distribution as do most measures of physical and mental abilities.

Steiger's theory and the attribution of chance causation were based on the close agreement between the distribution of measures of corneal refraction and the binomial curve, $(p + q)^n$ where $p = q$. From this it is only a couple of steps to saying that total refraction is the result of chance grouping of independent elements. To test this application of the normal curve to total refraction, the static refraction data of the Kemf, Collins, and Jarman study[3] of 1829 boys and girls six years and

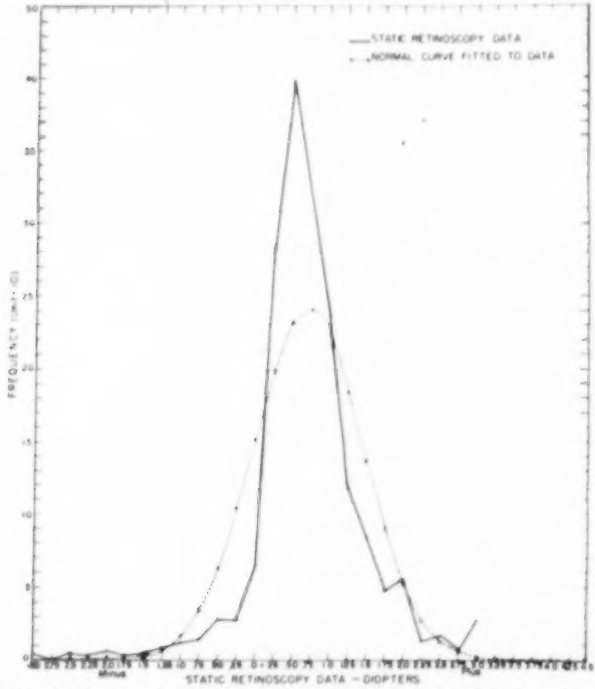

Fig. 1. The distribution of refractive errors under cycloplegic of 1,792 school children six years and up with a normal curve fitted to the same data. (From Kempf, Collins, and Jarman.)

up was plotted in Figure 1, and a normal curve was fitted to the same parameters. This data is restricted to the range between three diopters of hypermetropia and three diopters of myopia since no distribution of cases was made beyond these points. This restriction required the elimination of 27 myopes and 10 hypermetropes, leaving an N of 1792, and reducing the size of the standard deviation. Since the total number of cases omitted represents only two hundredths of the cases, the resulting error will not be sufficient to distort the shape of the normal curve fitted to this distribution. It is apparent from Figure 1 that the obtained distribution is highly leptokurtic and slightly skewed toward the myopic side. The amount of skewness and leptokurtosis may be estimated from the third and fourth moments about the mean, respectively. These calculations yield a value of .062 as compared with the value of zero for skewness in a normal distribution, and a measure of kurtosis of 6.869 as compared with 3.00 in a normal distribution. These measures support the conclusions drawn from the graph that

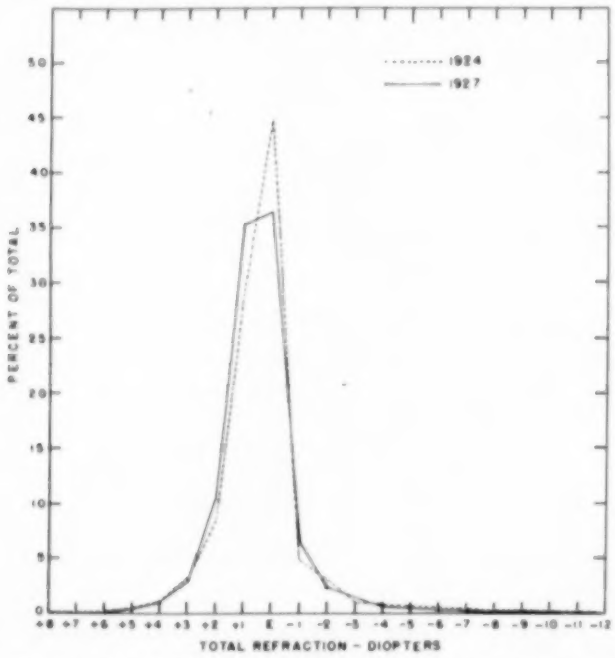

Fig. 2. Per cent of cases with various refractive errors of two groups of adults of approximately 8,000 subjects each refracted in the years 1924 and 1927. (From Betsch.)

the obtained distribution shows insignificant skewness and a very high degree of leptokurtosis.

It has been the practice of Steiger's followers to be more concerned about the amount of skewness than the amount of kurtosis of the obtained distribution. For example, Betsch[1] used data for static refraction obtained in his clinic as support for the application of the normal curve to total refraction data. Figure 2 represents the distributions of measures taken in the years 1924 and 1927. The curve for 1927 differs from that of 1924, because Betsch decided that it would be better to take the static reading without the use of a cycloplegic or fogging technique, since in the normal situation neither of these are operative. Further, he decided that since the measures taken are really inexact, it would be better to distribute them over several immediately adjacent intervals rather than keep them in the intervals to which they nominally belong. These changes serve to reduce the amount of leptokurtosis. To accomplish the same end for the degree of skewness, he eliminates all eyes with myopic crescents from the myopic end of the distribution. The results of these changes are seen in the adjusted

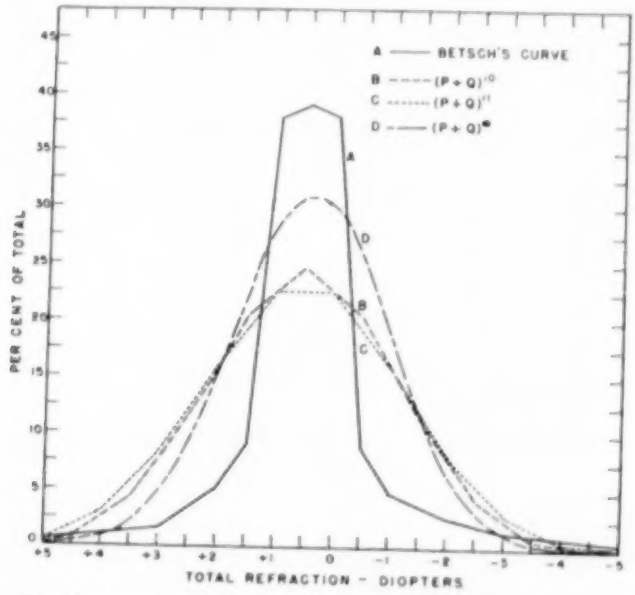

Fig. 3. Betsch's composite, adjusted curve based on the per cent of adults with various refractive errors with two binomials and a normal curve fitted to the same data.

curve of Figure 3. This adjusted curve represents Betsch's final result after all adjustments, and should be compared with theoretical distributions based on the same parameters. Although Betsch did not make such comparisons, several binomials and a normal distribution have been fitted to this data. The comparison of these curves indicates that even after the application of highly questionable assumptions, the obtained distribution of total refraction measures does not even approximate a normal distribution as far as the degree of kurtosis is concerned. Some recent experimental studies by Norton[5] indicate that the degree of kurtosis is more important than the degree of skewness in bringing about significant deviations from the normal curve.

By application of the type of reasoning employed by Steiger[7] and deplored here, it is possible to demonstrate that the purchase of new automobiles is a matter of chance. Figure 4 presents the frequency

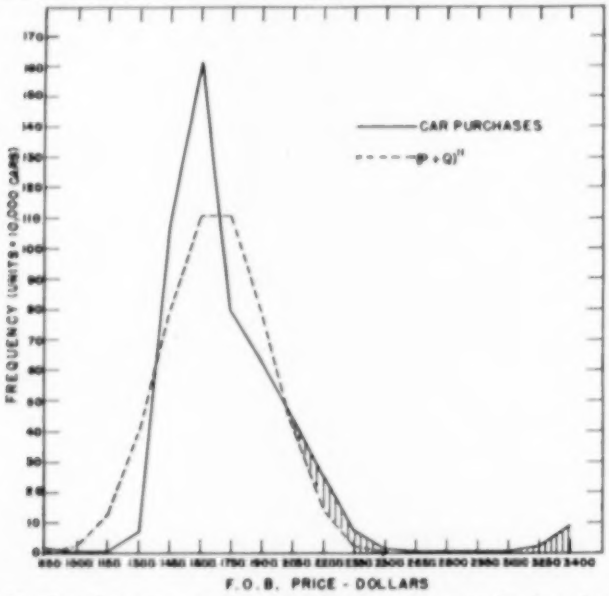

Fig. 4. Number of new cars purchased in different price ranges for four door sedans during 1951 with a binomial curve fitted to the same data. (From statistical summary Automotive Industries, 1952.)

of purchase of cars in different price ranges for the year 1951. Since this distribution is highly leptokurtic and skewed toward the high priced end as compared with the binomial $(p + q)$,[11] it is necessary to make some adjustments. If we assume that the purchase of high priced cars

is influenced by desire for prestige, we may adjust our curve to eliminate cars so effected. This adjustment will serve to eliminate most of the skewness of our distribution, but will leave the high degree of lepto-kurtosis. These data represent the price of the standard four door sedan. If we take the price range produced by any one manufacturer we will find cars lower and cars higher in price than the four door sedan with more of the lower priced models sold than higher priced models. If we adjust our curve for the price range and eliminate most of the high priced cars on the basis of our first adjustment, we may distribute the frequencies over adjacent intervals in much the same manner as Betsch[1] did with his refraction data and achieve an adjusted curve similar to that shown in Figure 5. As may be seen, this curve

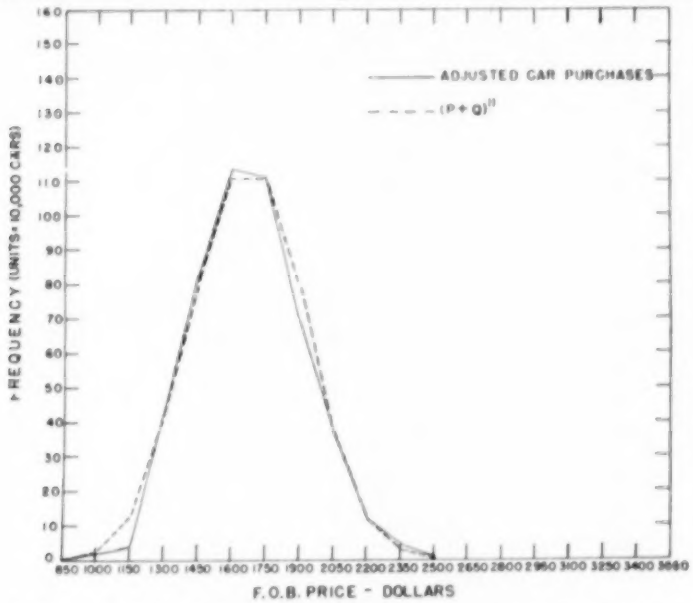

Fig. 5. New cars purchased curve adjusted for prestige value and different priced models with a binomial fitted to the same data.

closely approximates a binomial of the form $(p + q)^{11}$ thus showing by the same line of reasoning employed by Steiger and Betsch, that the purchase of a new car is purely a matter of chance. If we carry the fallacy of imputing causation because of similarity of distributions to the absurd, we may say that corneal refraction is caused by the purchase of new cars since the curves are similar.

The evaluation of the independence of refractive elements may be based on Stenstrom's[6] conclusions that there are slight correlations between dioptric elements, a moderate correlation between refractive error and depth of the anterior chamber, and a pronounced correlation between axial length and refractive error. On the basis of Steiger's[7] theory there is no reason to expect any correlation between elements and certainly no reason to expect a high correlation between axial length and refractive error. The fact that any correlations exist would refute a strict interpretation of the biologic theory, and the fairly high correlation between axial length and refractive error would be difficult to explain by any modification of it.

A third evaluation of the biologic theory may be made in terms of the comparison of other growth phenomena which are usually considered to be closely related to hereditary influence and the changes in refractive error with age. Figure 6 shows two theoretical curves which

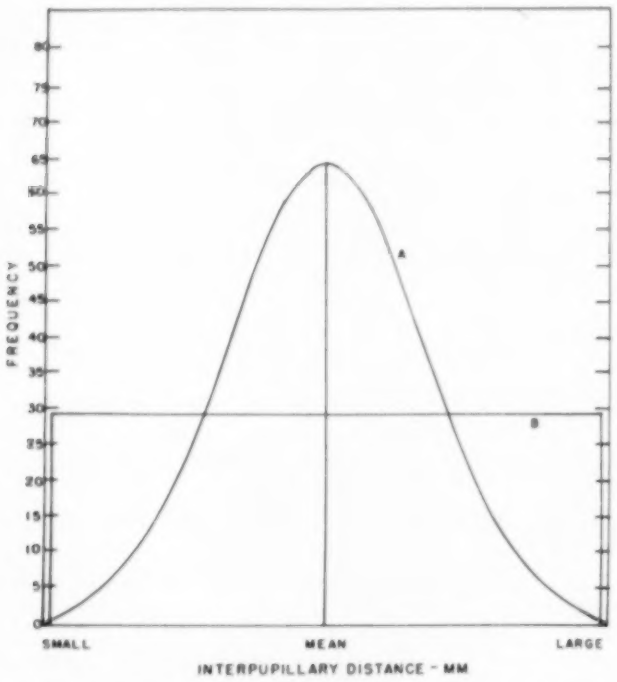

Fig. 6. Theoretical normal and rectangular distributions obtained on assumption of no growth relationship, respectively, between age and interpupillary distance.

would be obtained under different consideration from a group of subjects of different ages if there were the same number of subjects in each age group. The rectangular distribution of interpupillary distance would be obtained if all the subjects in each age group showed about the same PD, if there was no overlap between age groups, and if the PD varies systematically with age. On the other hand, if none of the above assumptions were true, we might expect to get a normal distribution. Since PD increases with age, and the other conditions are generally true, PD's based on 29 subjects at each age level from 5 to 16 inclusive, distribute themselves in a platykurtic fashion, as is shown in Figure 7.

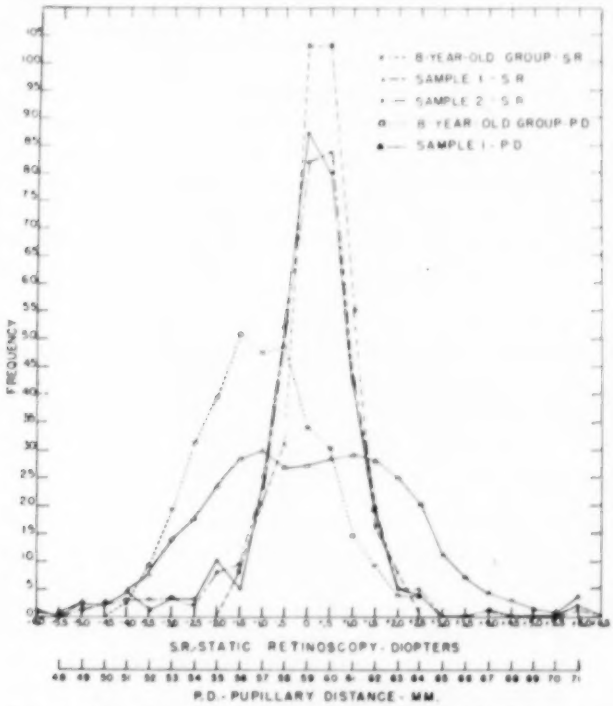

Fig. 7. A comparison of curves of interpupillary distance and refractive error based on one age level and a group made up of 29 children at each age level from 5 to 16.

For comparison purposes the distribution of PD's among children of the same age is plotted on the same axes. The same comparisons are made between the refractive errors of the same 348 subjects in the sample group and the refractive errors of the eight year olds. Two samples

were drawn from the population of 600 children to determine the nature of the sample with more accuracy. The two samples show no difference on the Chi-square test. The curves for refractive error are very similar for the eight year olds and the sample of all ages, which indicates that refractive error is not closely and systematically related to age in the same sense that PD is.

In summary, there is no justification for assuming that dioptric elements are independent and hereditarily determined elements associated by chance simply because they are distributed in a manner similar to a chance distribution. The occurrence of a correlation between the elements and between some of the elements and refractive error operates against the biologic theory. The distributions of refractive error shown in Figure 7 indicate that refractive error is not a growth phenomenon in the usual understanding of that concept.

In evaluating the near-work concept it is easy to find logical analogies to the process of adjustment to conditions of adjustment to conditions of work, but difficult to find clear cut experimental support for this theory. We are all familiar with the 97 pound weakling who became the world's strongest man and with the effect of weight lifting on muscular development. The process of adaptability through irritability is an essential characteristic of protoplasm and living matter. Since practically all parts of the body show adaptability to environmental conditions, and, indeed, must from the above definition, it is not difficult to believe that the eye should also be capable of making an adaptation to environmental conditions of near work. The high proportion of myopes found among university students, among the professional classes, and other groups which are occupied in more than usual amounts of near work, has been offered many times as an example of the adaptation of the eye to environmental conditions. While such changes are easily explained in terms of adaptation, they are difficult to explain in terms of a biologic theory. Wibaut[9] lists some of the hypotheses which have been advanced to explain the relationship between occupational class and myopia: Steiger claims that originally myopes gravitated toward the professions and academic fields because their myopia was no hindrance and actually a help. They passed their myopia on to their children who stayed in the same field. (It is difficult to see how this passing could occur when the elements vary by chance and are associated by chance.) Others have claimed that there are racial differences, and those races who have myopia go into the professions. And again, myopia and occupation are both related to intelligence and hence to each other, and occupations are selected on the

basis of intelligence. The hypothesis which Wibaut[9] accepts is that some children inherit a predisposition toward myopia and only develop it if the environmental conditions are favorable to its development, an hypothesis which is similar to that usually associated with the concept of intelligence.

Since the definitive experiments to support or refute the nearwork hypothesis have not been performed, any evidence one might use will be open to other interpretations. Only by the demonstration that there is a relationship between the amount of near work which an individual performs and his refractive state, a relationship which is independent of any other variables such as heredity and constitution, can this hypothesis be supported. Some of the opponents of the nearwork hypothesis have correctly pointed out that just because myopia increases as the number of years of schooling increases, there need not be a causal relationship between the two. There are several techniques which may be employed to overcome this objection. One is the use of the partial correlation technique to remove the relationship between myopia and age from the correlation between myopia and the amount of schooling. A second technique would be to determine the amount of close work which a group of children of different age levels do including the amount done in school. If the refractive error and the amount of close work are correlated for each age level separately, the effect of age will be eliminated and a better estimate of the relationship between close work and myopia will be obtained.

If such approaches were supported by systematic studies of the relationships of other variables such as diet, lighting, etc., it should be possible to gather evidence for or against the nearwork hypothesis, since we would then be determining the effect of different amounts of the experimental variable applied to randomly selected or matched subjects. The weakest link in such studies is likely to be the determination of the amount of close work which the subjects do. In a similar sense the use of co-twin control experiments will enable us to determine the role played by heredity in the development of the total refractive pattern of an individual or group of individuals.

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ABSTRACT

VISUAL ACUITY — RESULTS OF A SURVEY OF 10,000 PERSONS. R. H. Wilson and W. E. McCormick. Industrial Medicine and Surgery. 23.2.64-72.1954.

Visual screening tests were given by the AO Sight Screener to 10,372 employees of B. F. Goodrich Company. The survey, offered on a voluntary confidential basis, proved to be an effective means of promoting employee relations and improving employee morale. Also, besides the obvious benefits to the company, better quality of work and more efficient production may be expected.

Visual acuity was not found to be a great factor in causing accidents. Men under 40 had more accidents than those over 40, whereas unsatisfactory vision (less than 20/40) was found more frequently in men over 40. In other words, the older, more experienced workers were safest despite a greater incidence of impaired vision. Although the incidence of accidents did vary between age groups, it did not vary greatly within each age group for those who had satisfactory or unsatisfactory vision.

More females than males had uncorrectable defects and uncorrectable defects increased with age. Depth perception was the most frequent and monocular suppression the least frequent anomaly.

Glasses were necessary in 90% of the employees over age 50 and in 53.6% of all employees between ages 21 and 65.

ROBERT E. BANNON

COLOR BLINDNESS AND EMOTIONAL DISORGANIZATION*

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A previous study in the area of color perception indicated the need for further investigation of possible emotional or personality factors associated with color blindness.[1] This report presents some additional information concerning the relationships between defective color perception and signs of emotional disorganization.

PROCEDURE

A group of 100 male inpatients of the Alcoholism Study Unit of the Philadelphia General Hospital were examined with the new Dvorine color perception test.[2] This test was administered under standard conditions which included a source of illumination which had a color temperature of approximately 4000° K. This was in accordance with the test instructions which indicate that a 100-watt blue-daylight bulb may be used for testing. The light was incident upon the face of the plates at an angle of 45°. The patients viewed the plates from a distance of 30 inches and in such a way that their line-of-sight was perpendicular to the face of the plates. No more than five seconds was allowed for identification of each plate.

The patients were chronic alcoholics who had reached optimal physical rehabilitation prior to testing. In no case was a patient tested in less than three days after admission, the median period of elapsed time was seven days. The mean age of the sample was 42 years, with a standard deviation of 8 years, and a range from 20 to 67 years. The racial composition was 88% caucasian and 12% negroid. The intelligence and educational levels approximated those of the general population.

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*This article reflects findings which are incidental to a research investigation of the problems of chronic alcoholism currently being conducted at the Alcoholism Study Unit, Philadelphia General Hospital. This program for the study, treatment, and prevention of chronic alcoholism is sponsored by the Department of Public Health, City of Philadelphia in cooperation with the Division of Alcoholic Studies and Rehabilitation, Department of Health, Commonwealth of Pennsylvania.

The author wishes to express his appreciation for the encouragement given him by Dr. Martin D. Kissen, Program Director, Alcoholism Study Unit, Philadelphia General Hospital and Director, Soul Clinic, St. Luke's Hospital, Philadelphia, Penna.

Submitted on June 10, 1955, for publication in the July, 1955, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

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Although there are very obvious limitations in reporting the results obtained from such a biased sample, the information obtained was deemed sufficiently important to warrant this report. Any interpretation must take into consideration the fact that the behavior of this sample was characterized by prolonged periods of alcoholic excess. However, the color blind members of this sample do show significant differences from the rest of the sample, biased as it may be. Therefore, these differences may be considered as research leads or implications concerning the etiology, genesis, or concomitants of defective color perception.

RESULTS

There were slightly more chronic alcoholics classified as color blind (15%) than might be found in the general population[3] (10.5%). However, this is not a statistically significant difference in per cent (the "t" ratio is only 1.21). If the size of the sample of alcoholics were increased several fold and the difference remained the same, then it might become statistically significant. A statistically higher percentage of color blindness in the chronic alcoholic might indicate either the presence of some common etiological factors or the resultant effects of prolonged use of a substance toxic to the nervous system.

Psychiatric diagnoses were available on 13 of the 15 individuals found to be color blind. Of these, four exhibited clinical signs of chronic or acute brain syndrome, four were schizoid personalities, and one was termed a possible early simple schizophrenia in an inadequate personality. This is more than four times the representation in these categories than was found in non-color-blind group. These diagnoses were made in conformity with the uniform psychobiologic nomenclature of the American Psychiatric Association.[4] A *chronic or acute brain disorder* refers to a diffuse impairment of cerebral tissue function resulting in defects of memory, judgment, orientation, intellectual functions, and lability of affect. A *schizoid personality* is a personality pattern disturbance manifest in a lifelong pattern of behavior characterized by unsociability, emotional detachment, coldness, seclusiveness, introversion, and autistic thinking. It is a deep seated developmental defect which responds poorly to therapy, may regress to a frank schizophrenic reaction under stress, and seems premorbidly associated with the schizophrenic psychoses.

Thus 61.6% of those psychiatrically diagnosed exhibited a brain syndrome or schizoid personality. This compares with a frequency of 14.3% in the non color blind group of alcoholics studied. The case of possible early simple schizophrenia in an inadequate personality is quite akin to the schizoid personality disorder and this would tend to increase

TABLE I

Psychiatric Classification	Color Blind	Non Color Blind	Total
Total tested with color perception test	15	85	100
Total with psychiatric diagnoses available	13	56	69
Brain Syndrome	4 (30.8%)	1 (1.8%)	5 (7.2%)
Schizoid Personality	4 (30.8%)	7 (12.5%)	11 (15.9%)
Total Brain Syndrome and Schizoid Personality	8 (61.6%)	8 (14.3%)	16 (23.2%)

the significance of these findings. The brain disorders and schizoid personalities demonstrate pathognomonic signs of a malignant nature since they are believed to represent very fundamental defects in personality organization and the functional aspects of the cortical integrative processes.

In three of the remaining cases of color blindness there were histories of psychiatrically pathological reactions to alcohol. These included severe auditory and visual hallucinosis, transitory psychotic episodes, and delirium tremens.

In the remaining three cases of color blindness evidence of symptomatic psychopathology was not so pronounced. However, on various psychological tests the results in one case were similar to those found in latent or incipient schizophrenia and in another case were similar to cases involving organic deterioration. The remaining case featured only one minor transient psychotic episode and a history of blackouts for ten years.

Therefore, almost every case of anomalous color perception demonstrated one of the following: (1) clinical symptoms of unspecified organic involvement of the brain or a history of a psychopathological reaction to alcohol, (2) clinical evidence of a schizoid personality, or (3) psychological test results indicative of some fundamental disorganization of personality.

DISCUSSION

These results do not reflect adversely upon the great number of individuals with anomalous color perception in the general population. Certainly, the vast majority of the color blind members of society may well be in good mental health. But in the search for possible causes and concomitants of defective color perception there is being sought factual knowledge of possible differences between those who are color blind and those who have normal vision. This group of chronic alcoholics were exposed to the prolonged disrupting effects of a neurotropic drug, i.e., alcohol. The question to be answered is "Does this

disrupting influence bring forth any possible latent or incipient differences in those who are color blind as opposed to those who have normal color perception?" Differences were found. Now the problem is to discuss the possible inferences of these differences and any implications for further research on other populations.

Among the color defectives, two major categories of psychopathology were found. The first category includes the schizoid reactions which suggest a biological or psychological arrest of potential social maturity and high level of integrated functioning of the human organism. The second category includes both brain tissue involvement and pathological reactions to alcohol which suggest the disruptive effects of a toxic agent upon a constitutionally weak or susceptible organism. Thus, in one case there may be a lack of full maturity and in the other case a disruption of a precariously achieved maturity or high level of cortical functioning.

Of course, these results are not conclusive because the population sampled is biased. But these findings are highly significant for those who may design research investigations of other populations. The two major psychopathological categories found, represent very fundamental defects of personality or physiological constitution about which all too little is known at the present time.

In almost every case of color blindness, a careful review of the case history revealed substantial evidence that the cortical integrative integrity of the functioning organism was seriously impaired. This relationship between signs of integrative impairment and defective color perception tends to support the belief that the perception of complex color combinations results from a very high level of integrative activity in the neural hierarchy. What is considered color blindness is not an inability to see any particular color but a relative insensitivity to certain portions of the spectrum. If color perception is a high order cortical process of recent phylogentic development,[1, 5] theoretically it would be preferentially affected in any cortical damage. This is found in some lesions of the calcarine cortex which result, according to severity of the damage, first in loss of color perception, then in loss of form perception, and lastly in loss of capacity for awareness of movement and residual sensitivity to light.[6] Theoretically, this information may indicate that color perception may be affected by psychophysiologic involvements and maturational defects in structure or neurophysiology. It has been reported that emotional disturbances have more frequent somatic manifestations in the eye than in any other organ of the body.[7] No deficiencies of structure or neurophysiology have yet been reported, although it may be too early to expect such information from these complex fields.

That color blindness is more frequent in males than females may indicate some genetic predisposition in either structural or neurophysiological maturation perhaps associated with other constitutional defects, or the influence of the general physiological differences of sex during the growth of the organism, or a corrollary expression of dynamic forces in the psychogenetic development of the individual. If it is a type of emotional conversion, whether regarded as cortical suppression or disintegration, the implications for therapy are still unpromising because of its early appearance in the life of the individual. However, it would give some hope for re-training or re-education of the color defectives if an appropriate methodology could be developed.

The possible psychosomatic components of defective color perception are better understood if the following facts are remembered. First, the human organism does not respond to merely the sum of discrete stimuli perceived but rather to the integration and interpretation of constellations of stimuli affecting total processes. Each of a multitude of daily perceptual experiences is unique to the individual responding because of: individual differences in the capacity to organize: previous predisposing life experiences: educational and cultural backgrounds: work habits: and personality factors. Indeed, the modern day projective tests of clinical psychology permit structural and dynamic interpretations of personality based upon the perception of ambiguous ink blots[8] and scenes,[9] the perceptual-motor copying of designs,[10] and the drawing of familiar objects of the environment.[11] The processes within the individual which result in a unique personality configuration are active components in the perception and interpretation of any of the complex color stimuli found in everyday life. The interpretive significance of color responses to the Rorschach psychodiagnostic ink blots is the fact that the mode of reacting to color is indicative of an individual's general emotional reaction to the external world.[8] If the emotional adjustment of an individual is revealed by the manner in which he responds to color, then, conversely, it could be involved in the perception of colors.

SUMMARY

A group of one hundred male inpatients undergoing hospital treatment for chronic alcoholism were tested with the Dvorine color perception test. There was a slightly greater percentage of color defectives identified among them than may be found in the general population, although it is not a statistically significant difference. A psychiatric examination and review of the case histories revealed that those alcoholics with anomalous color perception showed a disproportionate representation of schizoid personalities, brain syndromes, and pathological reactions to alcohol. These disorders represent very fundamental

malignancies of emotional organization as well as the functional aspects of cortical integration as revealed clinically in individuals subject to prolonged use of a toxic neurotropic agent. The relation of color blindness to these psychopathologies might indicate that color blindness is more intimately related to emotional and cortical integrative factors than previously supposed. However, because of the small sample involved, further research is necessary to verify these results and conclusions.

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APPLIED OPTICS AND PRESCRIPTION WRITING*

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INTRODUCTION

The theory of spectacle lenses is a very important part of the optometrist's clinical training. Whether this knowledge is imparted under the name of physiological optics, applied optics, geometrical optics or optometry it remains basic knowledge for the practitioners in optometry who daily must write prescriptions for lens formulae. It is as fundamental to the optometrist as a thorough grounding in pharmacology is to the medical practitioner.

For a number of years optometrists have been improving their refractive techniques and furthering their understanding of the principles and application of visual training and orthoptics. With few exceptions they have failed to keep abreast of the advances made in the field of applied ophthalmic optics by which means they administer their "lens corrections or lens therapy."

The researches carried out at the Dartmouth Eye Institute by Ames, Lancaster, Ogle, Bannon and others have emphasized to a still greater extent the importance of the optical characteristics of lenses and have given to the ophthalmic professions an explanation of certain clinically observed facts and complaints which until this time had remained unexplained except for a tendency to classify them as neurotic or psychic in origin.

This paper proposes to review certain concepts in ophthalmic optics, to analyze their effects and to offer suggestions as to their use in clinical practice. Particular reference will be made to the nature and control of induced size effects.

PHYSIOLOGICAL BASIS OF DISCUSSION

The question of the existence and nature of a fusion center is far from settled in our present state of knowledge. However, those who have pursued the study of binocular vision concur that it is enhanced and made more efficient by: equality of ocular images and similarity of ocular images. They also recognized the fact that there are two component elements or phases to their conception of ocular images, these being the retinal phase and the cortical phase. The latter still remains

*Read before the annual meeting of the American Academy of Optometry, Toronto, Ontario, Canada, December 13, 1954. For publication in the July, 1955, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

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for the most part a subject of further research and study. The former, however, is more tangible and we do know that it can be controlled to some extent through the power, position, thickness of the lenses placed before the eye.

Bannon, quoting the results of the Dartmouth Researches,[4] reports that a one per cent size difference is clinically significant and that approximately three per cent of the population of Hanover, New Hampshire, revealed a clinically significant aniseikonia. Were this percentage found to hold in a general manner across the country it would indicate that aniseikonia is three times as prevalent as strabismus. It is estimated that strabismus is to be found in one per cent of the population.[4]

The recognition and correction of aniseikonia, if the condition were to affect three per cent of the total population, would not be such a simple matter as the frequency of the condition would imply. Carleton and Madigan, in a paper published in 1937,[5] have shown that there is no correlation between the aniseikonia measured and that expected from the amount of the ametropia. Therefore to the general practitioner in optometry who does not possess an eikonometer, aniseikonia remains a possible source of difficulty with which he is usually ill prepared to cope.

A more thorough understanding of the magnifying properties of spectacle lenses could provide an additional technique to be employed when conventional procedures have not produced satisfactory results with respect to relief of symptoms, or when the case leads one to suspect the existence of an aniseikonia regardless of the nature of the refraction.

THEORETICAL CONSIDERATIONS OF SPECTACLE MAGNIFICATION

The magnification properties of any correcting lens can be expressed[6] as

$$M = \frac{1}{1 - (D_1 \cdot e)} \times \frac{1}{1 - (D_v \cdot z)}$$

where the magnification is expressed as a ratio of the size of the retinal image in the uncorrected eye to that in the corrected eye; where

D_1 = power of the front surface in diopters

D_v = vertex power of the lens

e = is the reduced thickness or

$$\frac{\text{thickness in meters}}{\text{index of glass}}$$

z = is the vertex distance of the lens in meters.

This formula indicates the existence of four variables. However, for any one particular patient there are only three variables, because D_v or lens power is determined by the refraction and cannot be changed if the ametropia is to be adequately corrected.

Changes in the shape, thickness and position of the lens will affect the resulting magnification, thereby permitting some control over the size of the retinal image in the corrected eye. In juggling these various factors, the effect that changes in shape have on the position and effectivity of the lens must not be overlooked. The same is true of the effect of changes in lens size upon the sagittal depth of the back surface and the vertex distance.

As the points to be demonstrated are readily deducible from an analysis of the above formula, numerical examples will be employed as illustrations. For ease of comparison fixed values for "e" and "z" have been adopted.

Section 1—Differences in spherical powers create unequal but similar images.

Table 1 tabulates for easy comparison the magnification values for lenses of +1.00 D., +3.00 D., —1.00 D., and —3.00 D. It has been assumed that the four lenses have similar front surface curvatures. This would not be true if "standard stock lenses" were used.

TABLE 1

Magnification Values for a +1.0, +3.0, —1.0 and —3.0 Lenses Ground on Equal Curves and of Equal Thickness.

	+1	+3	—1	—3
D_i	+6.0	+6.0	+6.0	+6.0
Dv	+1.0	+3.0	—1.0	—3.0
e	.0016	.0016	.0016	.0016
z	.015	.015	.015	.015
M	+2.51%	+5.73%	— .52%	—3.33%
M_o — M_i	+3.22%		—2.81%	

This table indicates that plus lenses produce a positive magnification or increased retinal image while minus lenses produce a negative magnification or decrease in the size of the retinal image. In addition the table shows that for similar amounts of myopic and hyperopic anisometropias, plus lenses will produce greater image size differences between the two eyes than will minus lenses. This would indicate that the correction of hyperopic anisometropic cases need be given more serious consideration than the myopic case from the aspect of spectacle magnification effects.

The data given in Table 1 represents an ideal situation in that all factors have been standardized or controlled except the vertex power. In actual practice such a situation will not exist. For mass production purposes the manufacturers of ophthalmic lenses have adopted certain specific base curve series graduated according to powers. The practitioner should be aware as he writes out an anisometropic correction, of the inherent limitations of the standard base series.

Assume an example of O.D. +4.00 D.: O.S. +1.50 D. These lenses in the stock series may show a difference of three diopters in the front surface curvatures. Over and above the difference created by the difference in lens powers, two additional factors will influence the spectacle magnification, namely: (a) the lesser plus lens will have a lesser front curvature, (b) the stronger plus lens will have the greater thickness. It is to be noted that in concave lenses the thickness will be fairly standard irrespective of the vertex power. This is a second point which explains why myopic cases of anisometropia are easier to handle from the viewpoint of spectacle magnification.

Section 2—Cylinders create dissimilar images by introducing meridional size differences.

Because the powers and base curves vary in the axis and power meridians of cylindrical and compound lenses there will be corresponding variations in the magnification values of the two principal meridians. The difference in these magnification values is known as a meridional size difference. There are four different situations to consider.

TABLE 2

Meridional Size Difference for a +2.0 Cylinder for a Selection of Different Base Curves.

Lens	+1.0 ⁻ +2.0x90		+1.0 ⁻ +2.0x90		+1.0⁻+2.0x90	
Base	+6		+8		+10	
merid.	90	180	90	180	90	180
D_i	+6	+8	+8	+10	+10	+12
Dv	+1.0	+3.0	+1.0	+ 3.0	+ 1.0	+ 3.0
e	.0016	.0016	.0016	.0016	.0016	.0016
z	.015	.015	.015	.015	.015	.015
M	2.51%	6.06%	2.83%	6.41%	3.17%	6.76%
Diff.	3.55%		3.58%		3.59%	

A—*The same power of cylinder will produce equal (percentage wise) meridional differences irrespective of the base curve used, all other factors being constant, although the magnification in both principal meridians will increase as the base curve increases.*

Table 2 illustrates this statement.

B—*The same power of cylinder will not produce equal meridional differences with different spherical powers whether or not these powers are ground on the same base curve.*

Table 3 illustrates this point when the base is held constant despite the increase in powers. Table 4 repeats the same lens powers but with variations in base curves as in conformity with the standard stock series of one manufacturer. As in the previous example cylinders are ground on the front surface.

TABLE 3
Meridonal Size Difference for a +2.0 Cylinder in Combination With Different Spherical Powers on Similar Curves.

Lens	+1.0 ⁻ +2.0x90		+3.0 ⁻ +2.0x90		+5.0 ⁻ +2.0x90	
Base	+8.0		+8		+8	
merid.	90	180	90	180	90	180
D_s	+8	+10	+8	+10	+8	+10
Dv	+1.0	+3.0	+3.0	+5.0	+5.0	+7.0
c	.0016	.0016	.0016	.0016	.0016	.0016
z	.015	.015	.015	.015	.015	.015
M	2.83%	6.41%	6.08%	9.85%	9.51%	13.55%
Diff.	3.58%		3.77%		4.04%	

TABLE 4
Meridional Size Differences for a +2.0 Cylinder in Combination With Different Spherical Powers Ground to Different Base Curves.

Lens	+1.0 ⁻ +2.0x90		+3.0 ⁻ +2.0x90		+5.0 ⁻ +2.0x90	
Base	+7.50		+9.00		+10.75	
merid.	90	180	90	180	90	180
D_s	+7.50	+9.50	+9.00	+11.00	+10.75	+12.75
Dv	+1.0	+3.0	+3.0	+5.0	+5.0	+7.0
c	.0016	.0016	.0016	.0016	.0016	.0016
z	.015	.015	.015	.015	.015	.015
M	2.76%	6.32%	6.24%	10.02%	10.00%	14.05%
Diff.	3.56%		3.78%		4.05%	

A review of Tables 3 and 4 indicates an increase in magnification values as the power of the lens increases and also how the meridional differences increase as compared to the almost fixed values when the powers are constant and the base curves vary (Table 2).

These data, contained in Tables 2, 3 and 4, explain, the difficulty some patients have in adapting to a change in correction. It is sometimes found that a patient will not tolerate, in a new correction, the same cylinder he has previously worn with comfort prior to the change in spherical power, although the refraction does not indicate a change in cylinder power.

In the standard base curve series the curves increase when the spheres attain specified amounts. It is not uncommon to care for patients whose new corrections, because of an increase in spherical power, are ground on steeper curves. These changes in spherical powers, base curve and in all probability in thickness and vertex distance *can result* in an increased overall magnification and/or an increased meridional size difference which increases could create symptoms non-existant prior to the change in the prescription.

As a result of some difficulties encountered in routine practice it has been found satisfactory to order new corrections on the same base curves as previously worn. The flatter curve and the shorter vertex dis-

tance can offset to some extent the effect of increased powers. This same reasoning holds when duplicating broken lenses or when preparing duplicate prescriptions.

C—*Irrespective of the powers involved the meridional size differences will always be less when the cylinder is ground on the back surface of the lens.*

Of the two surfaces of a lens only the front surface has any direct influence on spectacle magnification. When the cylinder is ground on the front surface the value D_1 will vary in the principal meridians, being greater in the power meridian. Necessarily the value D_v is also greater due to the cylinder. This double increase in curve and power will create a specific meridional difference for a specific lens.

If, on the other hand, the cylinder is ground on the back surface D_1 remains constant for the principal meridians. D_v only will vary. The resulting meridional difference will necessarily be less in this instance than in the former. Tables 5 and 6 illustrate these points for both convex and concave lenses.

TABLE 5

Meridional Size Difference for a 2.50 Cylinder Ground on Front or Back Surfaces of a Convex Lens.

Lens Power	+2.00 ⁻ +2.50x90 plus cylinder		(assume +7.50 base) minus cylinder	
meridian	90	180	90	180
D_1	+7.50	+10.00	+7.50	+7.50
Dv	+2.00	+4.50	+2.00	+4.50
e	.0016	.0016	.0016	.0016
z	.015	.015	.015	.015
Mag.	+4.35%	+8.97%	+4.35%	+8.54%
Difference	4.62%		4.19%	

TABLE 6

Meridional Size Difference for a 2.50 Cylinder Ground on Front and Back Surface of Concave Lens

Lens Power	—2.00 ⁻ —2.50x90 *plus cylinder		(assume +7.50 base) minus cylinder	
meridian	90	180	90	180
D_1	+10.00	+7.50	+7.50	+7.50
Dv	— 2.00	—4.50	—2.00	—4.50
e	.0016	.0016	.0016	.0016
z	.015	.015	.015	.015
Mag.	—1.35%	—5.18%	—1.73%	—5.18%
Difference	3.83%		3.45%	

*On a plus cylinder in concave powers the higher front curve yields the weaker vertex power.

In clinical practice this fact of smaller meridional size difference when grinding minus cylinder could have value in the following circum-

stances: (a) when a patient who has never used a correction requires a cylindrical component of the order of 2.5 D. or more, it is unlikely that the optometrist will consider giving a full cylinder component. He will be guided by his own personal experience in giving a reduction in power of the cylinder. If the cylinder is going to produce spatial distortion it will be at a minimum if the cylinder is ground on the back surface of the lens. Also it will be found possible to prescribe more nearly the full cylinder thereby affording better acuity. (b) In cases of high unilateral cylinders, irrespective of the axis location. Such astigmatism is usually corneal and the anisometropia is therefore refractive in nature. Here aniseikonia is to be suspected. Carleton and Madigan[5] report that in 75 per cent of a group of patients corrected for aniseikonia and revealing a difference in refraction of 1 D. or more, the measured aniseikonia was in the direction expected from the cylinder axis position. In 14 per cent it was opposite and in some 11 per cent there was no measurable aniseikonia despite the anisometropia. (c) In those patients who are having difficulty in adapting to an increased cylinder power, rather than cut the cylinder and sacrifice acuity, a minus cylinder *could* be tried.

To those practitioners who have their own laboratory it will be evident that a minus cylinder is easier to insert in a frame, than a plus cylinder because eyewires are made to fit spherical base curves, usually a plus six. In metal zyl frames it is not always possible to rework the eyewires to the high curves found in plus cylinders. A heavy bevel on the front surface impairs the appearance of a lens; it is far less objectionable on the back surface.

If the foregoing analysis is correct, are not our lens designers confronted with a problem of determining a set of curves for high cylinder powers in single vision lenses?

Section 3—Sudden changes in refraction, especially if unilateral, will produce changes in magnification values of the new correction as compared to the former.

All sudden changes in refraction can be considered pathologic or traumatic in origin, but are refractive in nature. Such changes are the spontaneous luxation of the crystalline lens; surgical extraction in cataract; incipient cataract or diabetic changes. Depending on the suddenness of the refractive changes the individual may complain of changes in spatial orientation.

As monocular aphakia cannot be comfortably corrected and given binocular vision with conventional ophthalmic lenses these cases comprise a group outside the scope of this paper. Cataract cases in progress are still amenable to regular lenses. If the condition is bilateral and of

equal amount in both eyes, usually little difficulty will be encountered in getting patients to accept their new corrections. However, a few hypersensitive patients may report that things do not seem natural or normal. An attempt could be made to satisfy them by maintaining spectacle magnification in the new correction equal to or as close as possible to that found in the former prescription. If the condition progresses more rapidly in one eye, it can be expected that aniseikonia will eventually become manifest. These cases may complain of poorer vision in the eye more affected but also of some discomfort in using their eyes. Once again an attempt could be made to give greater satisfaction by maintaining the same magnification ratios as existed in the old correction.

Suppose a patient has worn +2.50 D. sph. O.U. for a number of years. Cataract develops but progresses more rapidly in one eye. The new correction is found to be +2.00 D. sph. and +1.00 D. sph. Rather than decrease the magnification of the +2.00 D. to equal that of the plus +1.00 D., it would seem more logical to increase that of the +1.00 D. sph. to equal the +2.00 D. sph. as this amount is closer to that to which the patient is accustomed.

Ogle and Burian[8] reported some years ago a case of increasing index myopia. This particular case did go on to a very marked degree of aniseikonia due to this unilateral condition. This case was remarkable not by the nature of the condition but the degree to which it progressed. The practitioner is not likely to see very many such cases. However, he is likely to see patients with incipient cataracts quite frequently. Nothing should be overlooked in making these patients more comfortable. Maintaining the spectacle magnification as nearly as possible equal to the ratio present in the old correction is a simple procedure and will be appreciated by the patient.

DISCUSSION

In this analysis an attempt has been made to indicate the effects which vertex power, curvature of the front surface, thickness and vertex distance of ophthalmic lenses can have on spectacle magnification. However, although a lens of a specific power and shape produces a specific *spectacle magnification* it does not necessarily follow that the *retinal image size will be changed by exactly this amount*. Carleton and Madigan have shown that the[5] measured aniseikonia is not correlated to the amount of the ametropia. This being the case the optometrist who does not possess an eikonometer must have some criteria upon which to form a decision as to the possible presence of an aniseikonia.

The following criteria are offered as helpful, but not absolute

guides, to the differentiating of clinical cases who could benefit from the application of the principles discussed herein. (a) The case history. A prolonged period of unsuccessful or unsatisfactory changes in correction and definite symptoms of discomfort in those tasks demanding critical binocular function. (b) Monocular vision more comfortable than binocular. (c) Sudden changes in refraction as previously outlined. (d) Differences in corneal curvatures with or without corneal astigmatism. (e) The presence of astigmatism especially if unilateral or of an asymmetrical nature and quantity. (f) The presence of a myopic crescent is indicative of an axial condition. Such being the case, the image size in the corrected eye will equal that of an emmetropic eye and an induced aniseikonia is not likely to occur. However, this consideration would not affect the presence of a true (inherent) aniseikonia were such a condition to exist in that individual.

At our present state of knowledge, it is now accepted that some 30 per cent of anisometropic conditions are due to axial causes, some 30 per cent to refractive causes and some 40 per cent to mixed causes.[7] On the basis of these statistical estimates one further rule could be proposed, namely: "Assume some 50 per cent of the anisometropia is due to refractive causes and correct accordingly, applying the principles just reviewed."[9]

The writer does not possess an eikonometer but has applied these principles for some two years. On the limited number of cases available no definite conclusions can be drawn. However, in at least two cases, subsequent eikonometer tests substantiated the diagnosis even to the extent of indicating that the corrections given were adequate to correct the measured aniseikonia. In a number of other cases such simple modifications to existing corrections as an increase in the front curvature by from one to four diopters eliminated subjective complaints. Finally, in a number of cases it was found necessary to modify new corrections in all respects, other than the vertex power, to be similar to the former satisfactory prescription. As a consequence of this sometimes painful experience—to us, the practice of recording base curves and thicknesses of the old lenses was adopted and these were duplicated in the new lenses whenever indicated.

SUMMARY

Some general principles relative to spectacle magnification have been reviewed with particular reference to preventing induced aniseikonia. Some criteria, useful in differentiating cases likely to benefit from the application of these principles, have been listed. Reference to their successful application in clinical practice has been made.

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NEW MEMBERS

The following optometrists have been elected to Fellowship in the American Academy of Optometry. The Academy welcomes these new members.

Dr. Gengt Burman, Stationsgatan 12, Skelleftea, Sweden.

Dr. Eugene M. Davis, 869 Main St., Manchester, Connecticut.

Dr. John N. Eggleston, 75 Prospect St., Milford, Connecticut.

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Dr. Paul G. Slaton, 804½ Excelsior Ave., Hopkins, Minnesota.

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AESTHETIC CONSIDERATION OF EYEWEAR IN RELATIONSHIP TO FACIAL AND OTHER CHARACTERISTICS*

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Since the advent of hi-fashion in eyewear, the ophthalmic dispensing of a frame has had to be considered in a different light. Correct styling influenced by fashion is the underlying problem that changes the picture. There are many factors that enter into the selection of a frame that will cosmetically enhance the appearance of the wearer. Here, as in any other artistic field, certain aesthetic principles are designated and must be applied to assure the patient of a frame that will be attractive for him or her.

The facial features are the first consideration to enter the picture. Of these, the influence of the eyebrows and the eyebrow line will be the first discussed.

Since the eyebrows add expression to the face, they should not be completely hidden from view. On the other hand, viewing them through the lenses would not be cosmetically correct. Rather the top of the frames should follow the contour of the eyebrow line with the eyebrow either completely or partially exposed. The exception to this would be the fad frames (such as the Temptress) which are designed to create an off-beat effect. In the dispensing of these frames, the odd shapes make the eyebrow factor of little consequence.

The facial characteristics also influence the frameweight that is recommended for the patient. A small face with small features should be properly balanced with a light or medium weight frame. The patient who appears to be "all-glasses" was fitted in violation of this rule. By the same reasoning, a large face appears to be out of balance when a light weight frame is worn.

The most attractive lens shape is our next consideration. Here to be applied is a rule found in the fields of art and fashion. Repetition of a line emphasizes the original line. Therefore a lens shape that will repeat an undesirable line in the face should not be selected. For example, if a woman has a round, full face that is not flattering, a lens shape that is definitely rounded would be avoided. Instead, a definitely angular

*Read before the second western regional meeting of the American Academy of Optometry, Los Angeles, California, April 17, 1955. For publication in the July, 1955, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
†Optometrist. Member of faculty. Fellow, American Academy of Optometry.

frame design would be chosen. In the male, the angular lines of the face are the most masculine and since these are the desirable lines to emphasize, all men's frames that are definitely squared in design are the most popular.

An accurate observation of the patient's personality also helps in the selection of the proper frame, for, by this method, you can judge what the patient is really interested in. The woman who walks into the office dressed as though she stepped out of VOGUE will not be satisfied with a frame styled with a conservative manner in a subdued color. On the other hand, a patient simply dressed is not going to enjoy wearing an unsual frame that is designed to attract attention to its wearer.

The selection of a frame is also influenced by the age group into which the patient falls. In children, the wearing of glasses in many cases presents a psychological problem. To offset this, it is necessary to make the wearing of glasses as enjoyable as possible. Following through with a popular theme is often the solution. For example, for the child who has the cowboy craze, frames trimmed with appliques shaped like horses or cowboy hats are available. The space patrol enthusiast can have rocket ships and guns on his frames.

To a little girl, dolls on the end pieces are an added incentive for the wearing of glasses. Youngsters also seem to enjoy frames that are miniature copies of their parents or their older brother or sister.

An even greater problem presents itself in the teen-age years. Social acceptance is of great importance and glasses are often resented. Since this is the age when novelties are the thing, frames that are a fad are not only acceptable, but also quite enjoyable. For example, these would include the bright, gay plaids, odd shapes, and trims that are definitely fadish in design.

In the older patient dark rims that completely surround the lenses offer an unflattering contrast to the lines and wrinkles that naturally accumulate with age. These patients usually look best in the two-tone rims, combination frames or light colored frames.

Of foremost concern to the patient is the color of the frame. This selection may be made in one of two ways, according to the general coloring of complexion, hair, and eyes or according to costume. The first to be considered will be the selection according to general coloring as applied to the woman patient.

First is the typical blonde—the patient with the fair skin, light hair and light brown or blue eyes. Although most colors can be worn by such a definite type, she wears all shades of blue or brown best. For a dramatic effect, black offers a vivid contrast to the general coloring.

Next is the patient with the same general coloring as the typical

blonde except that the hair is blue-black. This patient wears best all shades blue and black. To be avoided are all shades of brown.

The typical red-head looks best in most shades of green, blue and brown. Avoid all vivid shades that clash with hair coloring. This would include all shades of reds, fuschia, and most pinks.

The typical brunnette wears all bright and vivid shades well. If black or brown is worn it should be trimmed with a bright applique. To be avoided are the drab or dull colors such as grey.

The color selection for the Oriental, Indian, and Negro is the same as a brunette if the skin color is light. If it is very dark it is best to select a black or brown frame that blends in with the skin. A bright frame in this case would present too much of a contrast.

The intermediates are the patients who do not fall into any particular group. The hair color ranges from a medium or light brown with the absence of the definite color found in the blondes, brunettes, or redheads. Since there is such a wide variation in this group the trial and error method is best.

The gray-haired patient looks well in most pastel colors. Matching the color of the eyes can also be very effective. If the patient is prematurely gray, a black frame trimmed with silver is especially striking.

When a patient desires more than one pair of glasses for fashions' sake, it is best to match the costumes and accessories providing these colors are becoming. However, since the woman who desires a wardrobe of glasses is usually quite fashion-conscious, she is aware of the hues that do look best on her. Therefore the colors of the frames dispensed seldom present a problem.

A frame could also be dispensed to a patient not in the light of a fashion accessory with color predominating but as a piece of jewelry. Into this category would fall the gold and silver frames. Here, the problem of matching is gone for gold or silver jewelry is always correct regardless of the color of the costume. In such a case, the patient would probably have a preference to either the yellow or white gold and would make her selection accordingly. Not all of the style factors have been mentioned in this paper and none have been fully discussed. This report is intended to present some of the cosmetic problems that arise in ophthalmic dispensing and to offer some possible solutions.

AMERICAN JOURNAL OF OPTOMETRY
and ARCHIVES *of*
AMERICAN ACADEMY OF OPTOMETRY
Established 1924

Vol. 32 July, 1955 No. 7

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Publication and Academy Office: 1502 Foshay Tower, 821 Marquette Ave.
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Annual Subscription, United States and Canada, $6.00 in Advance; Foreign, $6.50; Single Copies 60c

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Published Monthly by the
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MYOPIA

The claim is occasionally made that certain optometrists seem convinced that orthoptics or eye exercises can cure myopia. It is possible that there are optometrists who emphatically hold these views—yet in discussing this subject with many optometrists who engage in visual training or orthoptics, one rarely if ever meets a practitioner who does not hedge considerably when the subject is brought up. Actually, only a few of these men seem particularly interested.

Not only would most optometrists be reluctant to make such a claim, but the great majority of practitioners would refute the claim of curing myopia at all. Some of those who use and prescribe visual training seem to feel that an improved accommodative convergence relationship may perhaps serve as a deterrent to the further rapid progress of myopia and that under certain conditions the actual visual acuity of the myopic patient may be improved sufficiently to warrant the use of the suggested techniques.

In a few sentences that summarizes the present day attitude of the great majority of optometrists in practice today towards the subject of myopia and its cure or control. As a group, optometrists are a rather conservative lot—and while they may listen or read about unusual and sensational techniques, they for the most part, are unwilling to try out these practices on their patients. This conservatism is one of the strong points of the profession, and it has assisted in making it difficult for fads, and the doubtful suggestions of some cults, to secure anything like a foothold within the large total of optometrists in private practice.

Now is it possible to cure myopia? With our present knowledge of the subject the answer is no. Pseudo-myopia or an accommodative spasm may be cured but myopia itself is no more amenable to a cure than is hyperopia. Considering what is now known of myopia, particularly after it has reached a clearly definable clinical amount, the condition seems to be one that cannot be eliminated or cured. It can be corrected with lenses and in some minor number of cases the patient's visual acuity can be improved, usually only slightly, by exercises. There is no trustworthy body of clinical or other research which indicates otherwise. Myopes are still myopes after treatment, by any and all known refractive clinical tests.

Accepting the foregoing as a conservative position on the clinical handling of myopic cases at the present time, what then should be done? Should we throw up our hands and abandon the future to the clinical tests and techniques of the past? Not at all. Should we continue to prescribe lenses and where applicable orthoptic techniques in the hope of arresting the condition and at the same time giving these patients normal vision? Yes, with reservations. The incidence and progress of myopia among young students is too high and too serious to their future well being to accept with complacency. We must look to the future when we hope more can be successfully done for these patients. We must now encourage and help finance more authentic research in the hope that from this type of study will come better techniques for us to apply in our clinical practices.

Not only must our research workers be encouraged to work on these problems but we must also support and encourage research by scientists in allied fields. Every avenue with any hope of success must be fully explored—and from this additional knowledge improved clinical progress may come. At this time, of course, no predictions may be made—but the profession of optometry owes it to the millions of myopes it serves never to be content with only what has gone before, but always to be working towards the improved techniques of the future.

CAREL C. KOCH

BOOK REVIEW

WHY JOHNNY CAN'T READ. Rudolph Flesch, Ph.D. Published by Harper Brothers, New York City. 222 pages. Illustrated. Cloth. $3.00. 1955.

This is a book which all those interested in the care of children's vision should read carefully and objectively, with a firm grip on their basic understanding of how the sense of vision functions and for what purpose. Not only does the book stimulate thinking upon the nature and purpose of vision in reading but it gives one a clear picture of the "convincing" arguments which are being raised against the educationalists' widespread adoption of the "word method" of teaching reading as opposed to the "phonic method."

Flesch is an extreme exponent of the "phonic method" and takes great pains to prove his point. Yet, this reviewer found, within Dr. Flesch's presentation, the most convincing indications that he is wrong in extolling the phonic method as being far superior to the word method.

The kind of reading ability Flesch talks about is completely different from the kind that anyone with a knowledge of visual function would appreciate. Flesch gauges reading ability by oral reading; a good reader being one who can convert printed symbols to speech sounds with maximum speed and efficiency. The people he is attacking (the educationalists and research psychologists) say that reading ability is to be gauged by one's facility in getting meaning in terms of action and objects, not just speech sounds from printed symbols. These people do not deny the value of phonics in teaching oral reading; even Flesch admits that. But, his presentation of this secondary facet in reading is out of all logical proportion.

The author draws on a great deal of experimental evidence to show how superior the phonic method is in teaching reading—oral reading. No one will deny this, but, it bears no relation to the real purpose of reading—getting meaning, not sound, from printed symbols. The "phonic method" insists upon hanging the reading skill on spoken language, which, strangely enough, has always been learned without formal training on a "word recognition" method.

Flesch concludes his book by encouraging parents and teachers alike to defy educational authorities and teach phonics, even providing a lengthy series of phonic exercises.

BRIAN J. COX

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INSTRUMENT REVIEW

WHAT THE COLOR DEFECTIVE PERSON SEES. Dean Farnsworth. Munsell Color Company, Inc., Baltimore, Md. $1.00. 1955.

This instrument consists of a reproduction of a color triangle upon which is mounted a rotating disc of clear plastic ruled with a series of slightly converging lines. By means of rotating the plastic disc to three designated positions, the color confusions of various color defectives can be quickly demonstrated. The colors which fall within the zones outlined by the ruled lines will be those most likely to be confused by the color defective subject.

The various color names are printed in the appropriate places in the color triangle. The colors along the outline of the triangle are designated in the Munsell notation. The colors within the triangle are designated by common color names, i.e., yellow-green, brown, dull purple, etc.

The device is attached to the inside of a stiff paper folder, 7¼ x9". Instructions are printed on the page facing the color triangle. The cover page is attractively printed with the name of the device, and other pertinent data.

This graphic device will help both the color normal and the color defective to appreciate the confusion made by the color defective. It would be a very helpful device in discussing color defects with patients.

HENRY A. KNOLL

LOS ANGELES COLLEGE OF OPTOMETRY
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CURRENT COMMENTS

Terry Judith Parkins
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department; such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

A. O. A. MEETS IN MILWAUKEE

Dr. Norman B. Hays, Niagara Falls, was elected president of the American Optometric Association at its 58th Annual Congress at Milwaukee, June 6 - 10. He succeeds Dr. Samuel L. Brown, Fostoria, Ohio. Other officers are Dr. Rupert E. Flower, Visalia, California, president-elect; Dr. Lester H. Sugarman, Meriden, Connecticut, first

vice-president; Dr. Hoyt S. Purvis, Jonesboro, Arkansas, second vice-president; Dr. Joseph M. Babcock, Portsmouth, Ohio, third vice-president; Dr. H. Ward Ewalt, Pittsburgh, treasurer, and Dr. Ernest H. Kiekenapp, Minneapolis, secretary.

The meeting was attended by about 700 optometrists and guests who enjoyed the many entertainment features provided by the Wisconsin delegation. Trips through several breweries, a special evening of Germanic entertainment and a major league baseball game at the Braves Park did much to make the convention a success.

At the banquet Mr. Philip Perlman, former Solicitor General of the United States, made the address of the evening. He was introduced by Mr. William P. MacCracken, Jr., A. O. A. Washington Counsel.

Among the special meetings held during the Congress were the many college alumni luncheons, the meeting of the International Association of Boards; Beta Sigma Kappa; National Board of Examiners in Optometry; American Optometric Foundation; American Academy of Optometry; Association of Military Optometrists; Association of Schools and Colleges of Optometry as well as the several meetings of the Women's Auxiliary.

During the sessions, the House of Delegates adopted a new constitution and by-laws. At the close of the convention Dr. Hays said, "The organizational affairs of the A. O. A. are now in fine shape and our plans for the coming year are to work closely with local societies by assisting them with special audio-visual material to improve their local programs."

The 59th annual congress will be held in Miami, during June, 1956, and Los Angeles is to be the convention city in 1957.

NEWS BRIEFS

The British Optical Association Diamond Jubilee Foundation Lecture was given at the Royal Institution, Albemarle Street, London, on July 6 by Dr. Glenn A. Fry, director of the School of Optometry, The Ohio State University, Columbus. His topic was "Blur of Retinal Image." . . . Dr. James F. Wahl, Anna, Illinois, a past president of the American Optometric Association and member of the Academy, has been appointed Dean of the College of Optometry, Pacific University, Forest Grove, Oregon. He will assume his new duties on September 1. . . . Dr. V. J. Ellerbrock, School of Optometry, The Ohio State University, was the speaker at the May 22 meeting of the North Carolina Chapter, American Academy of Optometry, at Winston-Salem. His topics were, Aniseikonia, Anisometropia and Fusional Movements.

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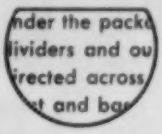

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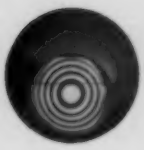

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